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ABSTRACT

This newsletter is for educators interested in developing lessons related to global climate change. The newsletter contains sample lessons, news items involving global climate change on an international scale, and background information on issues related to global climate change. (CW)

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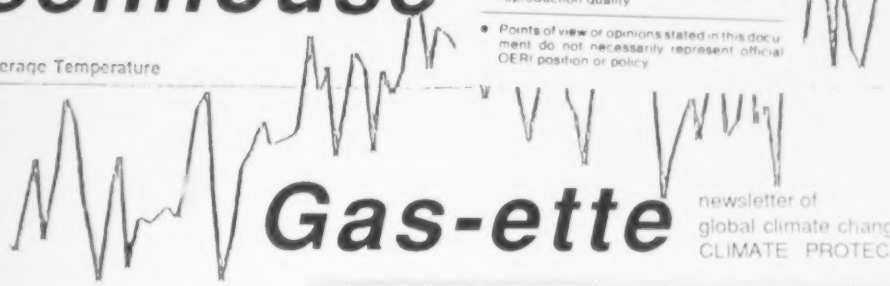
# Greenhouse Gas-ette




Fall 1988

newsletter of
global climate change education
CLIMATE PROTECTION INSTITUTE

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## The "Greenhouse Summer" is over but the memory lingers on

Mid-Western farmers despairing over the parched and blowing soil, barges stuck in the Mississippi River because of low water levels, forest fires raging out of control, record breaking heat waves across the country and the humidity of the tropics in Eastern cities - these are the images of the "greenhouse summer of '88."

Media events of this past year have brought the problem of global climate change to the attention of a large general audience. There have been major articles in TIME (Oct. 19, 1987), NewsWeek (July 11, 1988) and Business Week (Aug. 1, 1988) as well as innumerable news broadcasts and talk-show interviews.

The trigger for headlines across the nation and the statement that brought the greenhouse effect strongly into public discussion was made by James E. Hansen of NASA. Testifying before the Senate's Energy and Natural Resources Committee on June 23, 1988 he said, "Global warming has reached a level such that we can ascribe with a high degree of confidence a cause and effect relationship between the greenhouse effect and observed warming." Global climate change he said, " is already happening now."

This led Senator Timothy E. Wirth of Colorado to respond, "As I read it, the scientific evidence is compelling... Now, the Congress must begin to consider how we are going to slow or halt the warming trend and how we are going to cope with the changes that may already be inevitable."

Whether Congress will address this problem in any significant way remains to be seen. But educators have both an opportunity and an obligation to do so.

### Teachers' obligation

The opportunity exists because of the high degree of student interest. The obligation arises from the fact that young people now in our classes will be faced, through all their adult years, with decisions related to energy use and the emission of greenhouse gases.

For students to make intelligent choices, as responsible citizens in a technological age, they need to understand the underlying scientific principles of the greenhouse effect and the social, economic, and political consequences resulting from global climate change.

## Report on a work in progress

An Educator's Guide on Global Climate Change is being prepared. Lawrence Berkeley Laboratory's Center for Science and Engineering Education has agreed to publish the 30-40 page booklet. An announcement on its availability will be printed in the next issue of the *Greenhouse Gas-ette*.

The Guide will contain science background information and suggestions for classroom activities. There will be a section on the social and economic issues related to global warming. The outline for that section is reproduced below.

Social and Economic Issues

A. Ecological impact of high standards of living, high energy use
B. Changes in personal and community patterns of living
C. Economic disruption
   1. effect on infrastructure - coastal roads, irrigation systems
   2. effect on industry and employment
D. Effect on economic growth - locally and internationally
E. International relationships
F. Responsibilities to future generations
G. Achieving a sustainable world

**If you have any comments on the previous outline, or suggestions for classroom activities which can illustrate our topic, or any ideas you would like to discuss with colleagues, please forward them to:**

**CLIMATE PROTECTION INSTITUTE**
**5833 Balmoral Drive, Oakland, CA 94619**
**All materials used will be attributed.**

# Teacher suggestions

**Experiment - Temperature difference**

Our class set up 2 identical open top terraria. They were planted with a variety of locally obtained small plants which were matched as to size, shape and position in the container. They were watered in the same manner with precisely measured equal quantities of water. The one variable was an infra red lamp which was placed over one of the containers. It was positioned so that the temperature in one terraria was 10° C higher than the other. After two weeks there was a noticeable difference between the two containers.

Contributed by:
Anthony Carrera; Bridgeport, CT

**Science/Society lesson - "Designers of the future"**

With the cooperation of a social studies teacher in my school we held an unusual series of parallel class sessions for our 10th grade students. The results exceeded our expectations.

We called the mini-unit "Designers of the future". In science class we discussed the environmental problems produced by human activities. In social studies class the students examined the impact of those problems.

The students were then called upon to be "designers of the future." Teams presented their proposals for changes which they thought would lead to an environmentally sound world.

The only restriction we imposed on the students was that they had to show that their proposals were "possible." When we analyzed the proposals we found that they could be grouped in the following categories:

1. changes in personal life style
2. new legislation
3. redesign of existing technology and industrial practices
4. development of new energy sources and new inventions

In science class the proposals were reviewed for practicality and effectiveness. Their effect on the quality of life and the social, economic, and political "costs" were discussed in the social studiesclass. The proposals were modified and copies were made available to each student in the grade.

Finally, a vote was taken to determine the order of priority and degree of acceptability of the proposals.

Contributed by:
Patricia Thomas; Denver, CO

## Changing our address - and a personal note

Just in time to avoid this summer's hot and humid weather on the East Coast, the office of the Climate Protection Institute moved west in June.

Ensconced on a hillside in Oakland, CA, cooled by the winds of San Francisco Bay and retired from the routine of a professional science educator there is more time and energy to devote to educational activities related to global warming.

During the summer we worked closely with curriculum developers at the Lawrence Hall of Science, U. of C.- Berkeley preparing a two-week unit on global climate change. That material is currently being field tested.

The work of developing educational materials on global warming is continuing at the Lawrence Hall of Science and at the Science Education Centers of DOE National Laboratories. The *Greenhouse Gas-ette* will keep you informed.

# SCIENCE NOTES

## Another "Effect"

First there was the "greenhouse effect."

Then there was the "Goldilocks effect" - Mars is toooo cold; Venus is toooo hot; but the Earth is juuust right! (see Scientific American, Feb. 1988)

Now there is the "golf course effect." Dr. Robert Balling, director of Arizona State's Laboratory of Climatology, reports that in the desert city of Palm Springs, CA the average temperature has dropped 2° to 3° C in the past 15 years.

It is generally well known that the asphalt and concrete of cities create "heat islands" as they absorb and store radiant energy from the sun. Dr. Balling notes that Palm Springs had experienced a warming trend until the 1970's, when that trend was reversed. The only major change in land use has been the construction of a number of golf courses in the area. The irrigation of greens, trees and fairways has resulted in air cooling as the water evaporates from the vegetation. An increase in humidity has also been observed. This is a good example of how human activity can change climate.

Now if all the deserts could be converted into golf courses....

## Photovoltaic advances

Despite the fact that Federal support for basic research on changing sunlight directly into electrical energy is now less than 1/4 of what it was in 1981, there have been some notable advances.

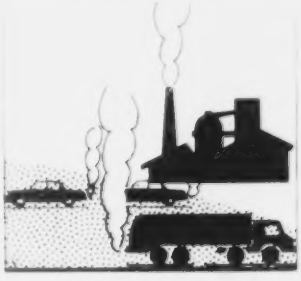
The Chronar Corp. of Princeton, NJ, a manufacturer of solar energy cells, is preparing to build a 50-megawatt photovoltaic electricity generating plant near Los Angles. The power produced will be sold to the Southern California Edison Co. Current technology converts only about 6% of the energy of the sunlight. But better things are on the horizon.

A new solar cell developed at Sandia National Laboratory in Albuquerque, NM converts 31% of the incident light into electricity. It does this by using 2 layers of light absorbing materials. The top layer is made of galium arsenide which absorbs light from the blue end of the spectrum. Red end light passes through to a silicon layer below, where it is absorbed. A plastic sheet of lenses above concentrates the light on an array of the new cells. A maze of microscopic electrical junctions at the bottom provides a new method for combining the electrical output.

This new approach can, in the opinion of Sandia scientists, increase the efficiency of collection to 35% within the next few years. For comparison, the average efficiency of coal or oil-fired electric generating plants is about 34%.

## Heavy note

Each year 5.4 billion tons of carbon are added to the atmosphere. That is more than a ton for each person on the planet.



## International conference on the changing atmosphere and a lesson for the classroom

At the end of June delegates from 48 countries met in Toronto to discuss the human effect on climate. It was agreed that an average global warming of between 3° and 9° F was likely to occur before 2050 and that it was largely the result of human fossil fuel burning and deforestation.

The conferees came to the conclusion that, unless the current rate of emission of greenhouse gases was curtailed, humankind would suffer severe consequences. The group made several recommendations.

A report on the conference is provided on page 6. It could be used as a reading assignment and, together with the questions below it, might serve as the core of a class discussion on the problem. Your comments are welcome.

## Conservation encounters of the second kind

Although the term energy conservation is used to describe all kinds of energy-use reduction, there are two different methods. The difference between them is important, since they bear on the quality of life.

Many people equate energy conservation solely with energy-use curtailment. Cutting back on energy-use is, indeed, one way to conserve it. But it often entails, and always suggests, personal sacrifice. There is an actual or implied reduction in the quality of life.

True conservation of energy calls for performing the same amount of work but with less energy. The difference is between turning the home thermostat down during the winter, saving heat energy by a reduction in comfort, and saving the same amount of heat energy by insulating the house and preventing heat loss.

Another example of the difference between curtailment and conservation is reducing the number of miles driven and increasing the efficiency of automobile engines so that they produce more miles to the gallon.

To achieve the energy conservation practices necessary to significantly reduce carbon dioxide emissions probably requires that both methods be employed. However, ingenuity and resourcefulness can accomplish much in energy conservation without a reduction in the quality of life.

Set your students to work on the problem.

## Good news about conservation

Scientist Art Rosenfeld and his team at Lawrence Berkeley Laboratories (LBL) have been hard at work on energy conservation research for a long time. Their message is that inexpensive and low-tech strategies are the most effective ways of reducing energy demand and, thereby, cutting carbon dioxide emissions. Some of their recommendations are:

• Reduce electrical energy demand for air conditioning by:
1. planting shade trees - "Properly located trees reduce air conditioning electricity use by as much as 50%."
2. switch to light-colored surfaces on roofs, streets and parking lots
3. paint houses with reflective paint (When Greek villagers decided to whitewash their homes they had the right idea.)

• Discourage energy waste by raising user taxes. (Taxes on U.S. gasoline average about 29 cents per gallon. Western Europe taxes range as high as $2 to $3 per gallon.)

• Establish and apply efficiency standards for electrical appliances. (In some states this is being done. Public information is needed to inform consumer choices.)

• As some states already do, require utility companies to prove that new generating plants would cost less than other options, such as cogeneration, wind generation, or promoting efficiency, before permitting new construction.

• Use intrared reflection and other new techniques for insulating glass windows. (One third of all U.S. heat energy escapes through closed windows. Saving that heat would be the equivalent of saving more enery than flows through the Alaskan Oil Pipeline System

• Use more efficent lighting fixtures (Screw in fluorescent blubs are available. A 16 watt fluorescent can replace a 60 watt incandescent and save 3/5 of a barrel of oil each year, in addition to giving more light.)

• Buy energy efficient automobiles (Art Rosenfeld estimates that an improvement of 0.1 mile per gallon in U.S. cars would save 20,000 barrels of oil per day.)

The U.S. spends 11.2% of its Gross National Product (GNP) on energy. Japan, in contrast, spends only about 5%. According to Rosenfeld, the U.S. is wasting $220 billion a year and raising the cost of American products.

### A graph for students to use

The graph U.S. Primary Energy Use reproduced on page 5 contains good news.

Prior to 1973 the GNP was in lock step with energy use. Conventional economic "wisdom" declared that any increase in GNP would enevitabily entail an increase in energy use. Since 1973 energy use in the U.S. has been relatively constant but the GNP has increased.

The difference indicated on the graph is the amount of energy saved by current conservation practices. Rosenfeld states that the implimentation of some of the new technologies are already saving several billion dollars a year in energy costs. He predicts that U.S. energy consumers will save roughly $100 billion annually in the years to come if they choose wisely.

# What Can We Do About Global Warming? - A sample lesson

**Activity - World Conference on Global Climate Change**

In this role-playing activity, the students are divided into teams that represent different interest groups. The first job of each team is to learn about the group whose identity they are asked to assume, and to plan their strategy for a World Conference. In the Conference each student is a "delegate." The challenge will be to plan proposals for effective, positive and cooperative global actions, while keeping in mind the group's own objectives and needs. As a warm up, give your students copies of the report "International Meeting Calls for Hait.." to read. (see Page 6 of this newsletter) Discuss the questions.

Assign students to one of the special interest groups. They are:

1. Environmental activists
2. Industrial developers
3. Developing nations
4. Nuclear power advocates
5. Future generations of human beings
6. Rights of animal and plants

Give each group copies of their own information sheet. (see below) They are to divide the responsibility for their class presentation so that each student has a point to make. Make sure that each group prepares answers to the following questions as they prepare for their report:

1. What specific proposal or proposals will your group make that will mitigate the effects of global warming while keeping in mind your group's needs and objectives?

2. What strategy will your group use to advance its proposals?

3. What point will each team member make?

If possible, arrange chairs in a circle. Then. acting as facilitator, have each group make its presentation and recommendations. Write these on the chalkboard or a large sheet of paper.

Facilitate a discussion about each idea. Synthesize ideas and modify recommendations when necessary. Then, hold a vote on each idea that remains on the list.

**Follow-up homework assignment:** Ask your students to write a list or a short essay about what they can do, in the real world, to mitigate the effects of global warming. Tell them to consider actions that they can actually carry out, either as individuals, with their family, as a class, or as community action projects.

Discuss the students' homework the following day. Encourage the students to follow through with some of these projects.

**Note to teachers:**

We would appreciate your evaluation of this activity. Are there some changes you would suggest?

CLIMATE PROTECTION INSTITUTE
5833 BALMORAL DR.
OAKLAND, CA 94619

B.

**Reference Sheet - Environmental activists**

Note: Remember that your goal is to present arguments and recommendations to reduce global warming that will, at the same time, promote the point of view and interests of your group.

1. Increased carbon dioxide, methane, nitrogen oxides, and CFCs (the greenhouse gases) are producing the trend of global warming called the greenhouse effect.

2. The expected rise in average global temperature of 3 to 5°C in the next 20 or 30 years will cause untold hardships. It will destroy some habitats. Changed rainfall patterns will affect the food supply. (The 1988 summer drought in the mid-West has been cited as the kind of weather that we can expect to increase in frequency.)

3. Sea level rise due to the melting of ice will flood and destroy existing wet lands upon which a portion of the marine food chain is based. Salt water will also inundate coastal aquifers.

4. The rise in greenhouse gases had been linked to the rise in industrialization and, therefore, mitigating actions that are necessary would include; energy conservation, recycling, reforestation, finding alternative energy sources, and change in the energy wasteful lifestyle of the industrialized world.

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**Reference Sheet - Industrial development advocates**

Note: Remember that your goal is to present arguments and recommendations to reduce global warming that will, at the same time, promote the point of view and interests of your group.

1. It has only been through the efforts of industry that standards of living of the world have been raised.

2. The average life expectancy of all human beings has been raised by the production and transport of goods and services. That production and transport requires energy.

3. Who would want to reduce their energy use and thereby reduce their standard of living?

4. Industry should not be limited. If entrepreneurs are left free to respond to the needs of the public, they will develop those innovations which will most benefit humankind.

5. Additional environmental demands on industry will simply raise the prices of goods and services. If protecting the environment needs capital investment, governments should supply the money. If all people benefit all should pay. Don't put the burden on industry.

C.

**Reference Sheet - Nuclear power advocates**

Note: Remember that your goal is to present arguments and recommendations to reduce global warming that will, at the same time, promote the point of view and interests of your group.

1. Energy is necessary to maintain and improve a decent standard of living. The fossil fuel energy supply must come to an end. Not only through exhaustion of its supplies, but because of the damage it does to the world's environment. Extraction scars the Earth and burning changes the climate, in addition to producing acid rain.

2. We need a source of power which will produce energy without producing greenhouse gases, and we need that energy source now.

3. Nuclear power can be made safe. France produces 1/4 of all its electrical needs through safe, simple nuclear power plants.

4. The technology now exists to build safer, clean nuclear power plants.

5. Waiting for new alternative non-atmospheric polluting sources of energy to be developed adds daily to the carbon dioxide burden the Earth is carrying.

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**Reference Sheet - Advocates of the rights of animals and plants**

Note: Remember that your goal is to present arguments and recommendations to reduce global warming that will, at the same time, promote the point of view and interests of your group.

1. Without plants and animals human beings could not exist. But besides their benefits to humans plants and animals have their own rights.

2. Increased global temperatures and deforestation will destroy many existing habitats and cause the extermination of untold numbers of species.

3. Biological diversity is necessary for the benefit of all animals and plants including humans. It would be diminished as world habitats are affected.

4. In many countries current laws make it a crime to be cruel to animals. In some communities you can be arrested for leaving an animal in a closed car on a hot day. Our society is saying that an animal has the right not to be victimized by human actions. But isn't that what we are doing if we let them suffer and die as we change the world's ecosystem? We must immediately stop the emission of greenhouse gases.

D.

**Reference Sheet - Representatives of developing nations**

Note: Remember that your goal is to present arguments and recommendations to reduce global warming that will, at the same time, promote the point of view and interests of your group.

1. We need the same sort of economic growth which the industrialized nations have enjoyed in order to improve the standard of living of our people.

2. We recognize that industrialization has its environmental costs, but why should we be asked to reduce our impact on our own land after the industrialized nations have decimated theirs? It is the industrialized countries who have fouled the world. Are we to remain undeveloped so that they can enjoy the kind of life that we are denied?

3. We have the right to exploit the natural resources of our own lands just as others have done without legislation, or even verbal, interference from outsiders.

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**Reference Sheet - Representatives for future generations of human beings**

Note: Remember that your goal is to present arguments and recommendations to reduce global warming that will, at the same time, promote the point of view and interests of your group.

1. Our disruption of the world's ecosystem by increasing the average global temperature has broad ethical ramifications. It raises serious questions concerning the correctness of our actions.

2. Due to our technological development we now have the unprecedented power of acting. What we do affects the whole world. Changing the world's climate will affect the future - forever.

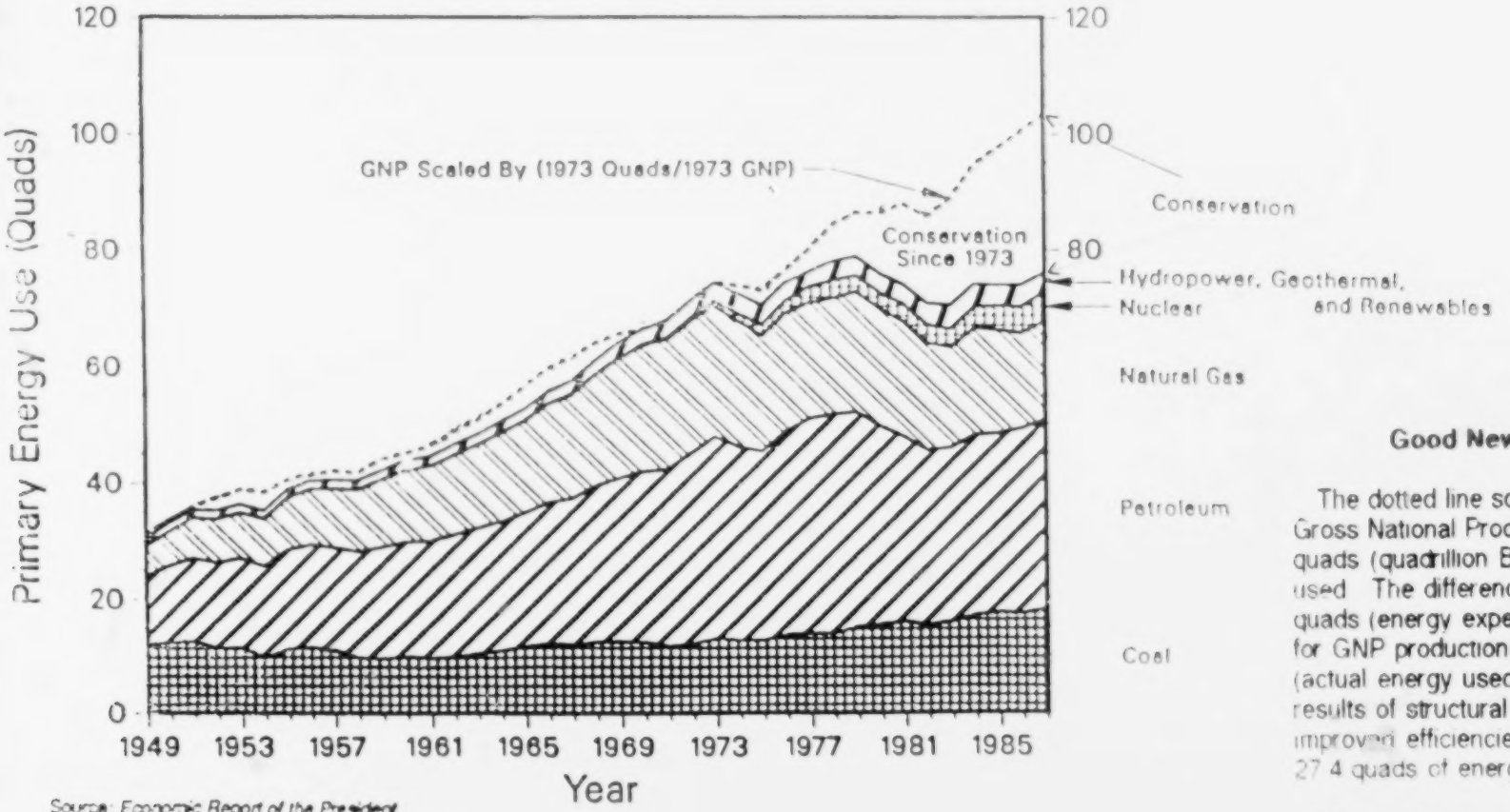
3. We also have the unprecedented ability to foresee the long-term consequences of our actions. We have the freedom and power to make choices. It is within our power to control our technology.

5. What right have we to impose on future generations detrimental environmental conditions? What gives us the right to alter the world for our benefit? Do we have the right to ignore those who are not present and have no voice in the decisions that will affect their lives?

6. We have the capacity, the knowledge, and the ability to make choices concerning the lives of future generations. We also have the obligation not to act to harm them.

For all of the reasons mentioned above we must reduce the emissions of the gases that can change our climate and we must take steps to reverse the damage already done.

## U.S. Primary Energy Use: Actual vs. Predicted by GNP




Source: *Economic Report of the President*, Council of Economic Advisors, January 1988, and *Annual Energy Review 1987*, EIA.

**Good News**

The dotted line scales the U.S. Gross National Product in terms of quads (quadrillion BTUs) of energy used. The difference between 102.8 quads (energy expected to be used for GNP production) and 75.4 quads (actual energy used) represents the results of structural changes and improved efficiencies that conserved 27.4 quads of energy in 1987 alone.

The good news is not only that we have saved this large amount of energy, but that we have done so without reducing the quality of life (as measured by the GNP).

# International Meeting Calls for Halt in Degradation of Atmosphere

TORONTO, JUNE 20 (Assoc Press)

Representatives of 46 countries attending a conference on the changing atmosphere called for quick action to save the atmo-sphere of the Earth. The meeting attended by government officials, scientists and environmentalists set goals for global reductions in the burning of fossil fuels.

The delegates agreed on the need for strong measures by the nations of the world to slow and then reduce the pollution that is warming the Earth. The pollution that concerns them is the increase in carbon dioxide and certain other gases emitted by human activities. The burning of fossil fuels is the largest single source of carbon dioxide pollution. The heat absorbing action of these "greenhouse gases" may be producing a general warming of the atmosphere that, it is feared, will cause significant world-wide climate change.

Among the measures called for by the delegates was a 20% world-wide reduction in the use of fossil fuels by the year 2005. They forecast the need for an eventual reduction on 50% in the use of coal and oil.

The conference was called by the Canadian government, and in-cluded officials of many countries. Its recommendations, however, are not binding on the countries that the delegates represent. It is expected that this additional public discussion by top scientists and environmentalists on the need for action will help move governments to action. The specific targets established recommended by the conference report may also help to promote action in the near future.

At its conclusion, the conference issued a statement which said: "Humanity is conducting an enormous, unintended, globally pervasive experiment whose ultimate consequences could be second only to global nuclear war. The Earth's atmosphere is being changed at an unprecedented rate by pollutants resulting from human activities, inefficient and wasteful fossil fuel use, and the effects of rapid population growth in many regions. These changes represent a major threat to international security and are already having consequences over many parts of the globe."

Some of the recommendations of the conference delegates were:

- Governments should establish a "world atmosphere fund" financed by a tax on fossil fuel consumption in the industrialized countries.

- Half the 20% reduction in fossil fuel use should come from more efficient use of energy and the other half from switching to fuels that emit less carbon dioxide.

- Nuclear energy should be reviewed as an option. But nuclear energy production should only be considered if certain questions are answered. Those questions deal with safety, radioactive waste disposal, control of potential war material, and environmental damage.

- The industrialized countries bear chief responsibility for the degradation of the Earth's atmosphere and should be responsible for remedial actions. They also should help the developing countries industrialize in ways that do not add to the problem.

## Review questions

1. Why are scientists, environmentalists, and some government officials calling for reductions in the use of fossil fuels?
2. According to the conference statement, what are the causes of atmospheric change?
3. What do you think of the recommendations and findings of the conference? Which do you favor? and why? Which are you opposed to? and why?
4. If you had been a delegate to the conference what actions would you have proposed?

## Toward a Global Environmental Education Ethic

- to recognize that the results of our daily actions soak into our natural surroundings and can accumulate there
- to appreciate that human activities have global effects
- to understand the need to weigh present actions in terms of future consequences
- to know that an action is right when it "tends to preserve the integrity, stability, and beauty of the biotic community." And that it is wrong when it tends otherwise.

Please let us know how you feel about the statement above and how you would add to it or change it.

### Wanted - for a biology experiment related to global warming.

In many organisms the rate of reproduction is temperature dependent. What we are looking for, however, is an organism whose appearance is temperature dependent.

Can you suggest such an organism for high school students to work with?

It should have the following characteristics:

1. physical development that is temperature dependent
2. temperature dependent features that are easily identifiable
3. easily cultured/grown/raised/bred in the classroom
4. short life cycle
5. freely obtainable, inexpensive, or shippable by us to teachers

### Technical assistance on energy conservation available

Although it is not recommended for answering students' homework questions, the Department of Energy maintains a toll free telephone information service on energy conservation and renewable energy technologies. The National Appropriate Technology Assistance Service (NATAS) can be reached at (800) 428-2525; (800) 428-1718 in Montana.

NATAS specialists are acquainted with current literature and government programs. They can discuss home and school energy improvements, community energy projects, and will even answer questions on subjects like innovative financing for a municipality's waste-to-energy facility.

They were very helpful recently in supplying information related to the installation of solar heating in our office.

## In this issue


- Teacher suggestions for classroom activities..... Page 2
- Science notes.....Page 3
- Good news about energy conservation.....Page 4
- "What can we do about global warming?"
  - a sample lesson.....4 Page Center Insert
- Toward a Global Environmental Education Ethic
  - a provisional statement.....Page 7


## Next Issue

- Trees and the Greenhouse Effect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**Please note our new address**

*"The amount and rate of climate change depend on how people behave."*
Dr Stephen Schneider


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# Greenhouse Gas-ette

Spring 1989

1950-1980 Average Temperature

newsletter of
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CLIMATE PROTECTION INSTITUTE


## Focusing on Forests

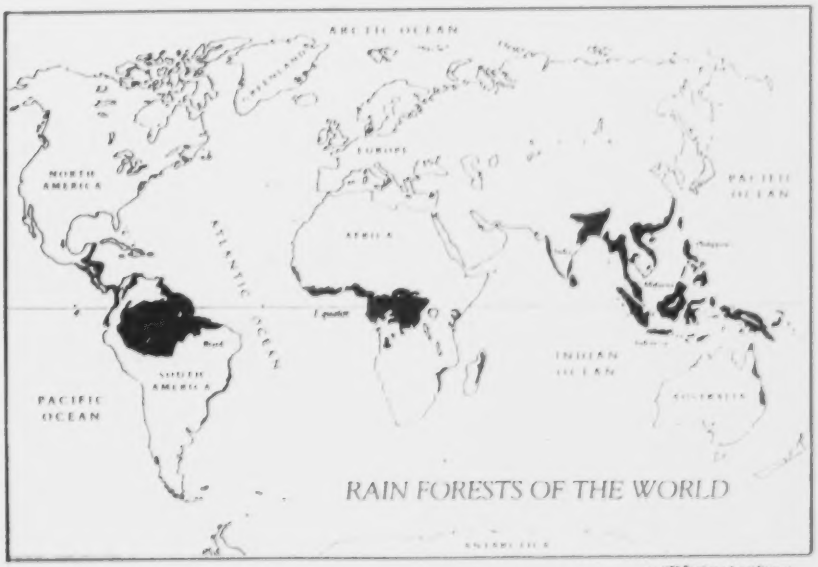
Perhaps the most successful of evolution's multi-cell creations are the trees. They stand in isolated splendor or in dense, complex forests all over the world. Trees evolved soon after the colonization of the land by green plants in the Devonian Period some 413 million years ago. They are intimately linked to the biogeochemical cycles of the Earth's ecosystem and are the primary contributors to the soil upon which all of terrestrial life depends.

### The Extent of Forests

Prior to the development of agriculture, forests covered almost half of the land area of the Earth. Now they have been reduced by human activities to one third of all land areas. They regulate our climate, protect our water resources, cleanse our polluted air, are home to millions of plants and animals, and provide us with important products. Half of the world's population depends on them for fuel.

All over the world forests are continuing to disappear. More than one and a quarter billion people are cutting wood for fuel and living space faster than forests can grow back. An area of tropical forest the size of Austria is being

(continued on page 2)




## Bi-Annual CPI Student-Made Video Award

**Announcement:**

Each June and January the Climate Protection Institute will award a Recognition of Excellence plaque to the teacher, with Certificates of Excellence to each of the students involved, for the production of the most effective student-made video submitted in the previous six months.

The topic of the video presentation is The problem of global climate change and what we (or our community) can do about it.

Tapes should be between 15 and 30 minutes long. Those submitted before Dec. 22, 1989 will be eligible for the Jan., 1990 award. Videotapes submitted after Dec. 22, 1989 will be judged for the June, 1990 award.

All submissions will be acknowledged. The winning videos will become the property of the Institute and may be used as part of public and educational presentations. All others will be returned with certificates of participation for each student who took part.

Send your videos to:

Climate Protection Institute
5833 Balmoral Drive
Oakland, CA 94619

## Focus on Forests

(continued from page 1)

felled every year. Since 1950 about half of the Earth's tropical forests have been cleared. (UNEP: 1987)

**Forests and Climate**

The largest reservoirs of carbon compounds on land are in the plants and soils of the forests. A small change in the metabolic processes that take place there can appreciably affect the atmospheric composition and thus the climate.

The affect of vegetation on world carbon dioxide concentration is obvious from the Mauna Loa Observatory graph of carbon dioxide concentration. (see below) Photosynthesis in the spring and summer result in a net storage of carbon. When respiration dominates in fall and winter the carbon dioxide concentration rises.

The burning of forests rapidly releases the carbon contained in the wood into the air as carbon dioxide. Carbon dioxide is also released as wood decays, although more slowly. Forest clearing, world wide, has released between 90 - 180 billion tons of carbon since 1860. During the same time period between 150 - 190 billion tons have been released by human combustion of fossil fuels for energy. (WorldWatch Paper 83:41)

The extra carbon dioxide burden our atmosphere is carrying today has been produced almost equally by the twin processes of deforestation and industrialization. If the reduced ability of the Earth to absorb carbon dioxide from the atmosphere due to the loss of trees is considered, then, to date, deforestation has affected the atmosphere more than industrialization.

**Regulating climate through transpiration**

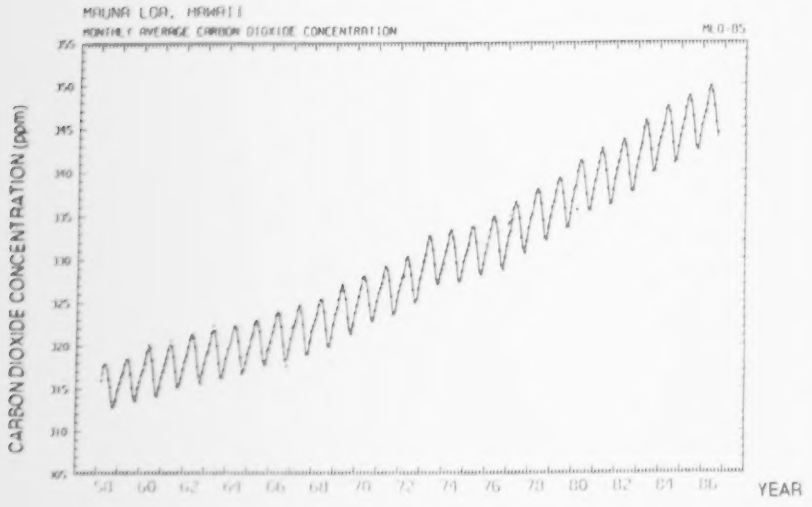
Besides the part they play in the world's carbon cycle, forests affect climate through the water they circulate. The process of evapotranspiration absorbs 70% of incident solar radiation. This leaves only 30% for heating the air and surroundings. Forests, therefore, act as a cooling mechanism in the tropics.

A tremendous amount of heat energy is absorbed in lifting the estimated 6.5 million, million tons of water that rises from Amazon Basin forests each year. Upper air circulation patterns move some of this moisture northward and southward and thus redistribute the tropic heat to the higher latitudes. As rain precipitates, the latent heat of evaporation is released. This heating effect is greater than that of direct sunlight. The sun heats a column of air less than 2°C per day. The same column of air receives 10-20° C per day of heat from air circulation depending on the amount of rainfall. (Ecologist, Vol. 15 #3:130, 1985)

Similar effects arise from other tropical forests of the world. Reduction in the amount of transpiration of the tropical forests will have climate effects around the world.

(For rainforest information see: The Science Teacher, Sept., 1988 Raven, P.,*Tropical Deforestation* )

**Carbon Dioxide in the Earth's Atmosphere**

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## Focus on Forests

**Forests and Climate Feedbacks - negative and positive**

(Note: When a system is disturbed, negative feedbacks are those changes that tend to reduce the disturbance to the system. The result is stability of the system or a return to equilibrium.

When a system is disturbed, positive feedbacks are those changes that tend to add the disturbance back into the system. The result is a system that moves toward breakdown.)

Negative feedback - Experiments have shown that a carbon dioxide enriched atmosphere can increase the growth of many plants. This will tend to remove carbon dioxide from the air. More plants will grow faster - producing more plants.

Positive feedback - During the climate warming period, dead vegetation decays faster due to increased bacterial action and carbon dioxide is released. A large amount of decaying matter will be produced by the vast numbers of trees that will die off because of their inability to adjust rapidly enough to the changed climate thus the amount of carbon dioxide released will increase.

Positive feedback - Forests absorb more solar radiation than open land, snow or ice. As the climate warms forests will slowly move poleward and gradually replace less energy absorptive areas. This will have a tendency to increase global warming and the further poleward migration of forests.

Unknown feedbacks - Transpiration from additional trees would tend to put more moisture in the air. The clouds produced may reflect more sunlight and cool the Earth. However, since water vapor itself acts as a greenhouse gas, the extra amounts might amplify the warming trend. Scientific studies show that plants grown under conditions of increased carbon dioxide utilize water more efficiently. Less water may be put into the atmosphere and greater runoff from forested lands may result.

## The Burning Question
### a new CPI unit available

CPI has a new 4 session unit available for students in 5 and 6 grades.

Outline

1. The process of burning and its products
2. Burning supplies us with energy and produces carbon dioxide
3. Respiration is a kind of burning
4. The carbon cycle
5. The relationship between carbon dioxide and the global greenhouse effect
6. What individuals can do about reducing the emission of carbon dioxide

Several follow-up lessons in Social Studies, English and Math are included.

We will be happy to send a copy of the unit to you. Feel free to reproduce it for you colleagues. Please mail $3.00 to cover printing and postage to: The Burning Question - CPI, 5833 Balmoral Drive, Oakland, CA 94619

## Kinds of Science Activities

The following is a list developed by Jacquey Barber, Lawrence Hall of Science Director of Chemistry Education, to help teachers develop activity based science lessons.

1. Introducing the students to a tool or technique for measuring

Usually start out with some explanation and demonstration. "Here is how this technique can be used." Then set up a challenge in which students use the tool or technique to gather data.

2. Investigating a phenomenon

The initial goal is to get an intuitive grasp of the phenomenon. A good way to start is by playing around with the phenomenon, making observations and forming hypotheses. This can be followed by more structured investigations and explanations.

3. Mastering a process skill

The goal of this type of science activity is to give students expertise in using a particular skill. An interesting, motivating context is the key to success in this kind of activity.

4. Performing an experiment

The goal is for students to learn how to plan and conduct controlled experiments. Only one thing must be changed from trial to trial, or you can't tell why the result is the way it is. A perfectly controlled experiment, in which all conditions are understood and accounted for, is the rarely achieved aim.

## Kinds of Science Activities

5. Simulations and games

The goal is to communicate a physical or biological process in a way that the students can visualize it and manipulate the process. This kind of activity should be followed by a student discussion of what was learned and it relation to the phenomenon that they were simulating.

6. Role play

Role play is a form of simulation in which the students represent other people in real world occupations. It usually starts with an introduction to the context and purpose, and includes a clear explanation of the roles that the students are to play.

7. Exploring real-world issues

Some very important social issues involve science and technology. These lessons can begin with an introduction of why the issue is important to students lives. They should include; clarifying what the issue is, the scientific principles that enable us to understand it, how science study can help us find out what to do about it, and what effective actions an individual or a community group can take. Extended student discussion should be part of the presentation.

The above list is not meant to be exclusive. In addition, many hybrid activities are also possible.

## CPI Goes International

The United Nations Environmental Programme (UNEP) prepares material on environmental and health awareness topics for distribution in Africa, Latin America and the Caribbean, Asia and the Pacific. The program is called "Outreach".

The packets of materials include comic book publications, activities and stories for young people in addition to background information for teachers.

A packet on the Greenhouse Effect and Global Warming is being prepared for World Environment Day in June. Climate Protection Institute has contributed materials for the packet.

## Global Climate Change as a STS Issue

Many State Departments of Education are interested in seening that issues relating science, technology and society (STS) are concidered by students. One of the goals of science education is a citizenry taht can intelligently evaluate the impact of technology on our lives.

The next issue of the *Greenhouse Gas-ette* will focus on global climate change as an ideal STS topic.

If you have any comments you would like to share, or activities you would like to suggest please communicate

Ask your social studies colleague if there is a lesson you could team-teach on this topic. What might it be like?

## Plants Produce $CO_2$ Too

Greenplants continuously oxidize their glucose just as animals do. In the process of photsynthesis they absorb more carbon dioxide than they give off. The result is net oxygen production.

To demonstrate plant respiration put a healthy green leaf plant in a covered container with a beaker of limewater and seal with petroleum jelly.

Set up another identical container without the plant. Put both containers in the dark or cover them with a black cloth for a day or two. Inspect the lime water for cloudiness as an indicator of the presence of excess carbon dioxide.

Germinating seeds also produce considerable amounts of carbon dioxide.

## Suggestions for Student Activities Related to Trees

**Science**

a) Explain how trees help to control climate by influencing wind, temperature, humidity, rainfall and the amount of carbon dioxide in the air.

b) Demonstrate the difference in water holding ability between forest and non-forest soils. Examine both kinds of soils under the microscope. Explain their water holding capabilities in terms of their structure.

c) Make a chart that show how a forest "makes" soil.

d) Make microscope slides of the epidermis of a number of different leaves to determine the number of stomata per sq. mm. Compare different plants. Are the number of stomata directly related to the rate of transpiration? Describe the function and operation of stomata.

(If the epidermis is difficult to remove put the leaves in boiling water for a few minutes. Stain with methylene blue or dilute Lugol's iodine. Many plants have stomata only on the bottom surface of their leaves. Floating plants have them on the top.)

e) For a procedure to demonstrate the entry of carbon dioxide into leaves through stomata see: Morholt, Brandwind & Joseph; *A Sourcebook for the Biological Sciences,* 2nd edition, pg. 174

(If the reference is not available send a self addressed envelop to CPI and we will forward a description of the method.)

f) Try to germinate seeds from tropical fruits. Determine the optimum conditions for growth.

g) Using the ideas of evolutionary biology and climate change explain why there are so many more different species of animals and plants in the tropics compared to the number in areas closer to the poles.

**Math**

a) If, as the World Resources Institute reports, the rate of destruction of tropical forests and woodlands is 11.1 million hectares a year, how many acres of forest are lost per minute? How may football field sized areas is this? (1 hectare = 10,000 square meters = 2.471 acres; 1 acre = 43,560 square feet)

b) Using the information from computer climate models, EPA scientists have calculated that future climate change could move the southern boundary of forest ranges to the north approximately 400 miles by the year 2050. Past studies have indicated that forests can migrate at the rate of 0.60 miles per year.

Sugar maples now grow within an area extending 900 miles from the Atlantic Coast to beyond the Mississippi River and northward for about 850 miles from Virgina to Maine. What is the current range area for sugar maples?

What will be the range area be in the year 2050 if the climate changes as expected? (Hint: As the southern boundary moves northward so will the northern boundary, but their rates are different. What is the difference between those two rates per year? How will that affect the 850 mile north-south range dimension in the years from now to 2050?)

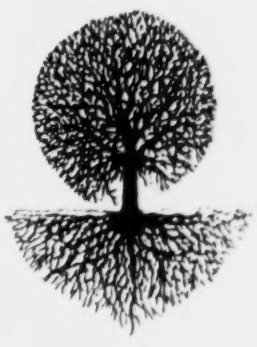
Locate the areas on a map of the United States.

**English**

a) Research the history of the poem "Trees" by Alfred Joyce Kilmer and the song made from it.

b) Explain the old English proverb, "Those who plant trees love others besides themselves."

**Your comments, criticisms and suggestions are most welcome. If you have ideas for other activities on global warming, please share them with us.**



## Suggested Student Activities

**Social Studies**

a) Keep a log of the amount of wood and wood products you use in a single day. What are the implications as you extend this use to the general population?

b) Use the Readers' Guide to Periodical Literature to find articles that relate to the destruction of the tropical rainforests of Central America. Explain how Americans contribute to this destruction.

c) Using the Readers' Guide find articles and explain the circumstances and policies that lead to the burning of the Amazonian rain forest.

d) Report on the activities that lead to the murder of the union leader and environmentalist Francisco Mendes Filho in Xapuri, Brazil on 12/22/1988.

e) Report on the actions of the World Bank as they relate to rain forest destruction.

f) Research and report on the international-debt-for-forest-preserve swap advocated by some environmentalists.

g) Hold a brainstorming session on the benefits of forests. Make lists under headings like; human subsistence, environmental, industrial, biological, aesthetic, hydrological.

h) Give a report on the Chipko, "tree huggers", movement of India. (see: Smithsonian, Feb., 1988)

## Reforestation as a response to the enhanced greenhouse effect

The managers of a small electric utility company in Connecticut were concerned that their new coal-burning power plant would add additional carbon dioxide to the already burdened atmosphere. They decided to set aside $2 million to assist in the planting of 52 million in Guatemala. (NY Times, 10/12/88)

The planting will cover 385 square miles. The quantity of carbon converted from gas to wood is estimated to be 15 million tons over the 40 year lifetime of the plant and will equal to the gas emitted from the plant.

The City of Los Angeles, burdenedwith its 5 million-vehicles, announced a 5 year program to plant 2-5 million trees. The aim is to provide both "sinks" for excess carbon dioxide and shade to cool buildings. (NY Times, 1/12/89)

Fossil fuel combustion has now surpassed deforestation as the major source of carbon dioxide emissions. While it is recognized that trees alone cannot prevent global climate change, reforestation is an important method of reducing the rate of increase of carbon dioxide.

Reforestation provides other benefits. Wood is needed for fuel and construction. Leaves can be used as foder. Forests provide habitats for important forms of wildlife. Trees can be effective in removing pollution from the air. Windbreaks occuping only one tenth or one twentieth of the land can protect precious top soil from wind erosion. Roots stabilize the soil and prevent water erosion.

Most of the time, loss of forests will increase the water flow of local streams due to the reduction in transpiration. This may prove to be temporary however, as the absence of the moisture put into the air will, in time, reduce the rainfall in the region. The Middle East and Greece are examples.

In additon, if overgrazing or poor crop production follow forest cutting, the soil compacts and looses its ability to absorb rainwater. Runoff rates increase, in some cases as much as twenty times. Sever flooding may result, as now is occurring in South Asia.

In Central America where 20% of the forest cover has been destroyed, erosion has hampered the effort to develop hydroelectric reservoirs. Silt has filled irrigation canals and coastal harbors.

Scientific studies have shown that urban trees have a potential for significantly reducing carbon dioxide emissions. The reduction is more from the indirect benefits of trees rather than their photosynthetic processes. In cities where there is a demand for air conditioning, trees planted on the south and west sides of building can reduce the energy demand for cooling by as much as 50%.

The evaporative cooling effect of leaves and the increase in albedo compared to black tops further reduces the need for air conditioning. The energy saved directly reduces the production of carbon dioxide.

A properly placed urban tree can, in effect, reduce ten times the amount of carbon dioxide in the atmosphere than its forest cousin.

## Teacher Suggestions

Using the Readers' Guide to Periodical Literature as a research tool, find the number of articles published during each year on the subject of the greenhouse effect or related topics and present the information in the form of a graph.

Describe what you think the following phrases mean or give an example of them, or both:
a) subjugation to nature
b) domination of nature
c) harmony with nature
d) stewardship of nature.

What connection do these ideas have to the problem of global warming?
Contributed by
**Paul R. Sullivan** - Pittsburgh, PA

Compare evaporation rates under different temperature conditions. Carefully weigh out equal quantities of moist sand. Set them up in identical containers (equal exposed surfaces). Keep air current conditions the same for both containers. Is there a linear increase in evaporation rate as the temperature increases linearly?
Contributed by
**Robert Hopkins** - Savannah, GA

Compare the quantities of water that evaporate from leaves by tying a plastic bag around leafy branches of plants that are subject to different temperature conditions. Be sure both bags enclose the same leaf area and receive the same amount of sunlight.
Contributed by
**Jeanne A. Levit** - El Cerrito, CA

## Turning students down

It a hard thing to turn down a student's request for information. When teachers give student s our address and suggest that they write to us for help we find ourselves in a very difficult situation.

Unfortunately, at the present time, we do not have the resources to service these requests. Please advise students that they can find all the information they need by consulting the Reader's Guide to Periodical Literature under headings appropriate to their research.

## Heavy note

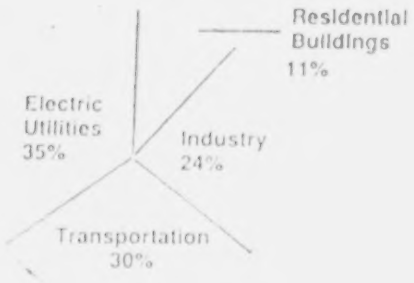
One ton of carbon dioxide is produced by each average citizen of planet Earth per year. North Americans are no average citizens however. Each one of us is responsible for the production of five tons of carbon dioxide per year.

One way to compare national populations is in terms of their environmental impact on the global ecosystem. Looked at in this way, the United States is one of the most heavily populated nations on Earth.

### Sources of Carbon Dioxide

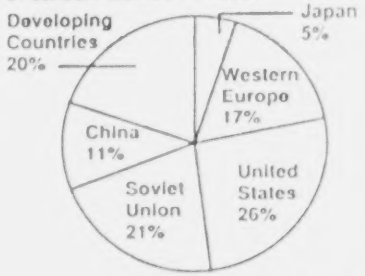
Percent of U.S. carbon dioxide emissions in 1987

Source: World Resources Institute




### Worldwide Emissions Of Carbon Dioxide

Percent contribution to the production of carbon dioxide in 1985.




Source: World Resources Institute

## HUMAN CAUSES OF CLIMATE CHANGE
### The Enhanced Greenhouse Effect

Causes of the modern increase in greenhouse gases:

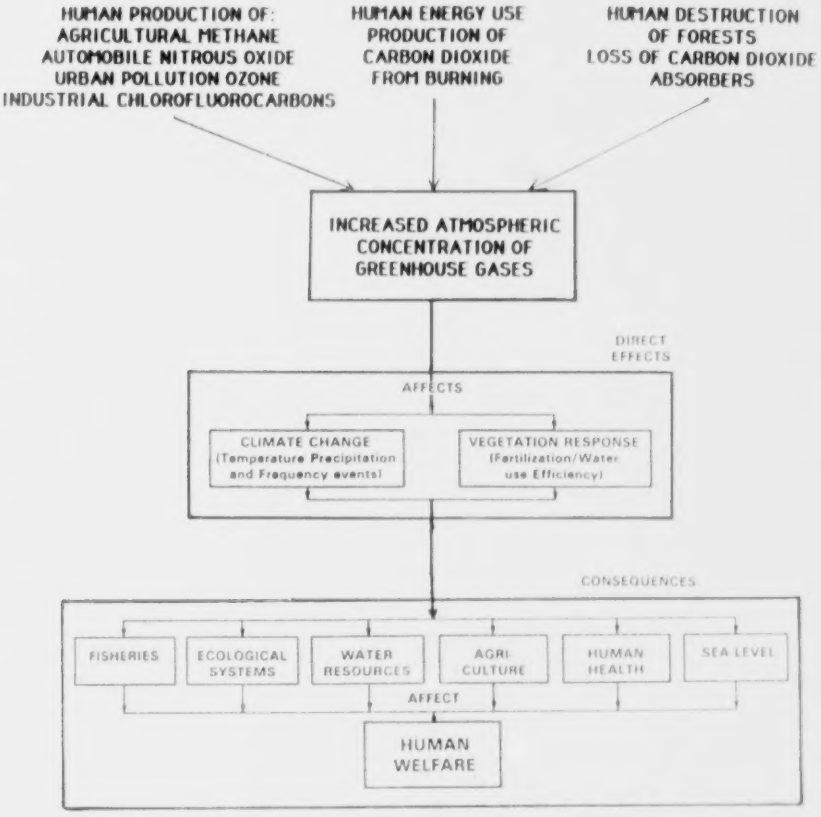
1. The industrialization of the world and high tech life styles - Most of our energy is obtained by burning fossil fuels which produce carbon dioxide. Automobiles, air conditioners and plastics add gases which contribute to global warming.

2. Population increase - Rapid increase in population in the less developed countries has lead to rapid cutting of forests for agricultural purposes and for firewood, reducing the quantity of carbon dioxide sinks. However, citizens of the developed countries are largely responsible for the vast increase in greenhouse gases.

3. Agricultural practices - The greenhouse gases, methane and nitrous oxide, are side products of the increase in rice and cattle production and of the widespread use of fertilizers.

4. Deforestation - Cutting forests not only removes a means of reducing carbon dioxide through photosynthesis but the burning of the forests and brush plus the exposure of forest soil increases the amount of carbon dioxide released into the air.

HUMAN ACTIONS - ENVIRONMENTAL CHANGE LINKAGE




Adapted from Lawrence Berkeley Lab (DOE chart

## CONSEQUENCES OF GLOBAL WARMING

based upon model predictions of a doubled carbon dioxide concentration over pre-industrial levels. An increase in average global temperatures of between 1.5 to 4.5 °C. is expected with a 6.7 °C (20 °F) increase in polar regions.

**Ecosystems**
- the problem of adapting to a rate of environmental change unprecedented in the history of the Earth
- forest stress - range of trees reduced
- increase in forest fires
- increase in pest populations and plant diseases
- loss of biological diversity - increase in the rate of extinctions
- deforestation - warmer soil speeds oxidation of humus - more $CO_2$
- loss of coastal wetlands
- wild life reduction due to the disappearance of water holes

**Water Resources**
- increase in evaporation - more cloud cover
- increase in global precipitation
- runoff change - more winter runoff, less spring and summer soil moisture
- failure of irrigation and river transportation systems
- coastal aquifers flooded by rising sea levels

**Agriculture**
- change in rainfall patterns - change in soil moisture affects food supply
- shift in national production of agricultural goods
- extension of frost-free growing season
- change in growth rates of crops and weeds
- increase water use efficiency of plants
- increase in range and population of insect pests
- increased demand for irrigation will lead to more water use conflicts
- less spring and summertime soil moisture more wind erosion of top soil

**Human Health**
- human stress - increased frequency and severity of heat waves
- death of some of the elderly
- increased need for cooling - energy demand increased in summer
- increase in heat-produced ozone pollution
- increased incidence and severity of respiratory disease
- increase in disease-carrying insects populations
- decreased productivity of workers
- loss of recreational ocean beaches

**Oceans**
- ocean level rise - expect 1 to 4 foot rise during the first half of 21 century
- increase in coastal flooding - effects on coastal infrastructure
- change in ocean currents
- ocean's ability to absorb carbon dioxide reduced by warming
- increased intensity of storms

**Surprises**
- synergistic effects of unknown magnitude
- rates of change
- operation of feedback mechanisms
- action of clouds

# The Long Term Carbon Cycle

The Earth circulates more carbon through its geochemical cycles than through the familiar cycle of photosynthesis and respiration. Over periods of millions of years the weathering of silicate rocks removes carbon dioxide from the atmosphere and the carbon is sequestered in ocean sediments.

Both carbonate and silicate based rocks are dissolved by the action of rain and ground water but because the carbonate rocks contain carbon themselves their decomposition does not result in a net reduction in carbon from the atmosphere. As rain falls through air laden with carbon dioxide some of it dissolves in the water and becomes carbonic acid ( $H_2CO_3$). The same is true of ground water as carbon dioxide is released from the decay of organic material in the soil.

The water washed stone releases calcium ions, dissolved silica and bicarbonate ions ($HCO_3^-$) which eventually make their way to the ocean. Plankton, corals and shell fish form calcium carbonate which, at their death, is deposited on the ocean floor.

The movement of the continental plates in the subduction zones drives the marine sediments into the mantle where the heat causes the formation of calcium silicates and the liberation of carbon dioxide. Soda springs and volcanic eruptions return the carbon dioxide to the atmosphere. The time of this recycling of carbon is of the order of 500,000 years.

## Feedback effects of the long term carbon cycle

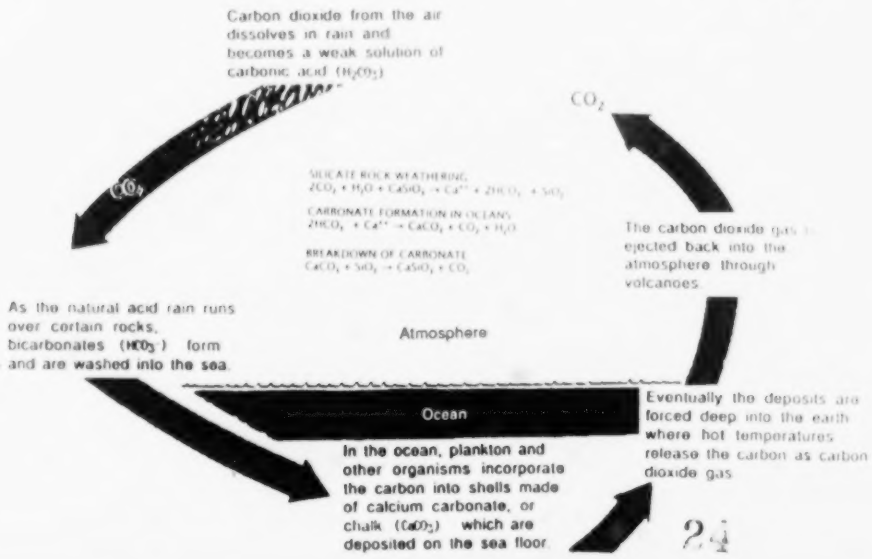
The long term carbon cycle acts as a negative feedback mechanism. It tends, in the long run, to maintain the temperature of the Earth within certain limits, producing a effect analogous to that of the household thermostat which regulates room temperature.

It works this way - If there is an increase in volcanic activity due to, perhaps, the movement of the crustal plates, excess carbon dioxide may enter the atmosphere. The Earth warms because of an increased greenhouse effect. More water evaporates, producing more rain which washes down as dilute carbonic acid. The result is an increase in the weathering of the rocks.

The increased supply of calcium and bicarbonate ions and the increased ocean water temperature stimulates the growth of calcium carbonate forming marine organisms. The fall of calcium carbonate to the ocean bottom increases. The excess carbon dioxide is buried in the ocean sediments which move slowly toward the mantle and eventual release in future volcanic activity.

In the meantime, the rain-weathering process has removed the excess carbon dioxide from the atmosphere and the temperature of the Earth is reduced.

For further information see:
Scientific American, Feb., 1988
*How Climate Evolved on the Terrestrial Planets*
Scientific American, Mar., 1989
*Modeling the Geochemical Carbon Cycle.*


Carbon dioxide from the air dissolves in rain and becomes a weak solution of carbonic acid ($H_2CO_3$)
$CO_2$
SILICATE ROCK WEATHERING
$2CO_2 + H_2O + CaSiO_3 \rightarrow Ca^{++} + 2HCO_3^- + SiO_2$
CARBONATE FORMATION IN OCEANS
$2HCO_3^- + Ca^{++} \rightarrow CaCO_3 + CO_2 + H_2O$
BREAKDOWN OF CARBONATE
$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$
The carbon dioxide gas is ejected back into the atmosphere through volcanoes.
As the natural acid rain runs over certain rocks, bicarbonates ($HCO_3^-$) form and are washed into the sea.
Atmosphere
Ocean
Eventually the deposits are forced deep into the earth where hot temperatures release the carbon as carbon dioxide gas.
In the ocean, plankton and other organisms incorporate the carbon into shells made of calcium carbonate, or chalk ($CaCO_3$) which are deposited on the sea floor.

## "Global Releaf" Project

The target year is 1992. The goal is to have Americans plant 100 million trees in their communities. The American Forestry Association, the organization sponsoring the project, estimates the those trees could absorb 18 million tons of the carbon dioxide we sent into the atmosphere each year.

In addition, urban trees can cool our overheated cities and save Americans $4 billion a year in air conditioning expenses.

For more information, contact:
Global Releaf
**The American Forestry Association**, P.O. Box 2000
Washington, DC 20013

## Greenhouse Action Project

For information related to legislative actions on issues of importance to global warming and suggestions on how you can help -

Contact: Bill Prescott
**Greenhouse Action Project**
Fort Cronkhite, Building 1055
Sausalito, CA 94965
415 331-8618

## READERS RESPOND

### On developing a global environmental ethic

In the last issue of *Greenhouse Gas-ette* a tentative statement of an environmental education ethic was offered. It included the following: "An action is right when it tends to preserve the integrity, stability, and beauty of the biotic community."

**Ed Hessler** of Minnesota Environmental Sciences Foundation made many interesting comments. Among them were the following:

1. The statement quoted (from Aldo Leopold, *The Sand County Almanac*) is very appealing.

2. Although the above is somewhat foreign to some modern systems of ethical philosophy there is growing interest in the idea of land stewardship.

3. The ethic to be developed should be a way-of-life ethic. Reflective, but participatory. A doing, acting injunction, e.g. act locally, think globally. Without an action component we distance ourselves from the sustainability of the globe. We must move past appreciating and understanding to action. We have real business in the world and we need to do it.

4. We need to reconsider our relationship to the Earth. We are more than visitors to Nature. A new word should be added to our ecological lexicon - **ecodevelopment**, a sustainable relationship between culture and Nature.

* * * *

Ed's remarks are very thought provoking. Jot down your reaction. Don't be fancy, phrases are fine. Send them along so they may be printed in this space.

### State of Washington considers a "Tree Bill"

**Stan Dick**, an interested reader from Olympia, WA, sends us the text of a new bill that the Washington State legislature is considering which will encourage the planting of shade trees and reduce electrical energy demand for air conditioning.

The proposed legislation provides for a subsidy of $25 per tree, up to a limit of three trees per residence. Its expressed purpose is to "provide financial assistance to residents for planting trees that will cast summertime shade onto residential structures."

We need the people in the states to the south and east of Washington to begin thinking along the same lines.

## CPI To Chair Panel Discussion At NSTA Convention

If you are going to attend the 1989 NSTA National Convention in Seattle April 6 - 9, a panel discussion on Saturday, April 8 at 2:00 may interest you.

The topic, Global Climate Change and Human Activities - Educators' Response, will be discussed by a distinguished panel of science educators.

The panel:
Dr. James Barr - College of Education, Nicholls State University, LA
Rodger Bybee - Associate Director, BSCS, Colorado Springs, CO
David Kennedy - Supervisor, Science and Environmental Ed., State of Washington
Dr. Kenneth R. Roy - Executive Director, National Science Supervisors Ass.
Dr. Herbert Thier - Associate Director, Lawrence Hall of Science, U. of C.- Berkeley

Even if you are not going to be at the convention you have an opportunity to ask the panel a question or two. Richard Golden of CPI will be moderating the session and will start the discussion with a few questions.

What would like to ask the panel? Quick! Mail your question to us.

A summary of the discussion will appear in the next issue of the *Greenhouse Gas-ette*.

### In this issue


- Focusing on Forests.....Page 1-3
- Kinds of Science Activities.....Page 3
- Suggestions for Student Activities.....Page 5-6
- Causes and Consequences of Global Warming.....Page 8-9
- The Long Term Carbon Cycle.....Page 10


**Next issue -** Global Climate Change as an STS topic

(see note on Page 4 this issue)

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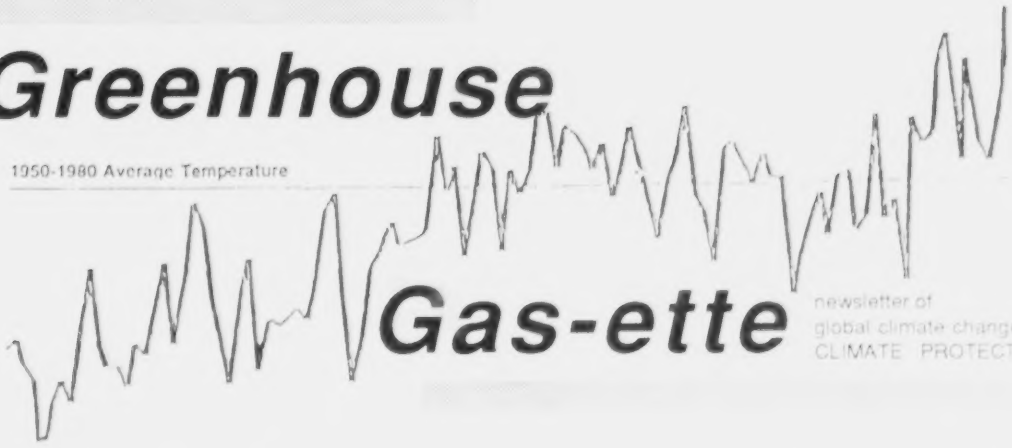
*"The amount and rate of climate change depend on how people behave."*
Dr. Stephen Schneider

# Greenhouse Gas-ette

Fall 1989

newsletter of global climate change education
CLIMATE PROTECTION INSTITUTE


## Global Climate Change - an Ideal Science, Technology and Society Education Topic

The National Science Teachers Association has defined the goal of science education as "the development of scientifically and technological literate individuals who understand how science, technology and society influence one another."

Instruction in STS is receiving increased attention by science educators. Guidelines have been suggested for infusing STS ideas and themes into science education. [1]

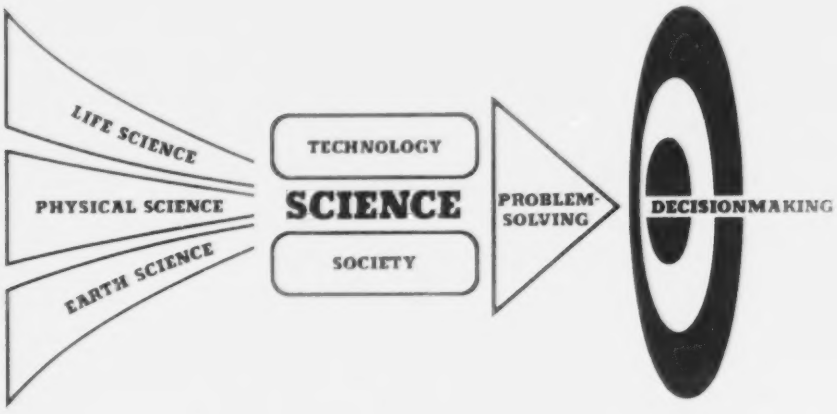
The guidelines appear below in the form of a series of questions.

• "Is the material on global warming applicable to the lives of our learners now, not just in the future?"

√ With the exception of topics related to personal health there is not another topic in science education today that is more important to the lives of our students.

We, of the industrial world, are the ones principally responsible for the change in the global atmosphere which is threatening to raise the temperature of world. Our students need to learn about global warming because there much that they can do to mitigate its future consequences."

(continued on page 2)




## Regional High School Needs Your Help

The science department of Nashoba Regional High School in Bolton, MA has a problem. The school has three separate and independent feeder school districts. The teachers felt that their freshman general science course was redundant for some of their students. They wanted a new interesting way to introduce their new students to science. The eight teachers and their department head, Sue Vogel, decided that a more stimulating and useful way to teach basic science principles was through an examination of global environmental issues.

### Your help needed in developing a new 9th grade science course from scratch

The Nashoba teachers started with the question, "What science related issues are important to modern civilization and should be part of the intellectual background of young people?" They found a tentative answer in the following topics:

- Introduction To Scientific Method and the Metric System
- Nuclear Energy
- The Greenhouse Effect, Global Warming, Deforestation
- Ozone Depletion
- Water Supply, Sanitation,
- Acid Rain
- Pollution, Toxic Wastes, Erosion

(continued on page 3)

## Global Climate Change as an Ideal STS Topic

(continued from page 1)

• "Is the material consistent with the cognitive development and social maturity of the students?"

√ It is suggested that fifth and sixth are the lowest grade levels that should get involved with global environmental problems. However, it is really high school students who can benefit most by learning to "think globally and act locally."

High school is an especially appropriate level to introduce global issues because it is at this age that students vastly enlarge their spheres of interest beyond their immediate community. They become conscious of their future role in the development of society. It is the time when resentment of the conditions that the present generation has bequeathed them can be transformed to positive action. It is an opportunity to help students recognize their own ability to take charge of their future.

• "Is the topic of global climate change important in the world today and is it likely to remain important for a significant portion of the students' adult lifetimes?"

√ The answer is obvious. Is the death of millions of species of plants and animals important? Is the danger to our food supply because of changed rainfall patterns important? If spring comes early every year, and days over 100 °F multiply, and snow pack in the mountains is reduced, is that important? Is it important that two fifths of the world's population live within a few miles of the coasts of the world and that the greenhouse warming will raise sea levels significantly?

It is hard to minimize the importance of global climate change. It has so many connections with the lives of our students. Although it is the past and present generation of adults are responsible for the emission of the gases and the deforestation that are the base causes of the problem, it is the students in our schools today who will feel the effects and bear the burden of decision making.

• "How will the study of global climate change help students understand how science, technology and society interact with one another and can they use this understanding to solve problems and make decisions at home, in school and in the community?"

√ Students who study how energy is produced and utilized will easily see how science and technology interact with one another. The connection between the production of greenhouse gases and energy use, agriculture and deforestation will show how human activities are interwoven with our global environment.

When our students understand the reasons that have led us to produce those gases; when they become aware of the social pressures and individual desires that result in the increase in emission of carbon dioxide through energy use, they will see the interaction of society and technology.

Whether they will use this knowledge to make the decisions that will reduce the impact of their lives on nature remains to be seen. All that teachers can do is to provide the information and assist the student to evaluate the results of different paths of action. The final course of action is a matter of individual choice and involves the set of values of the individual student.

Based upon the guideline questions it seems clear that global climate change is an ideal Science, Technology and Society topic. It has fundamental connections with the real world. It can be the basis for interdisciplinary science study since it incorporates aspects of many of the physical science-sence. But most important, it has vital connections with human life.

The political, economic and social consequences of global climate change are incalculable but must, somehow, be anticipated and prevented or mitigated. Education seems to be the only answer.

(For the STS questions above we are grateful to Faith Hickman, John Patrick and Rodger Bybee, authors of Science/Technology/Society: A Framework for Curriculum Reform in Secondary School Science and Social Studies, 1987. It is available from the Social Science Education Consortium, 855 Broadway, Boulder, CO 80302.)

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Climate Protection Institute
5833 Balmoral Drive
Oakland, CA 94619

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## Help a Regional High School Develop a New Science Course

(continued from page 1)

The teachers at Nashoba Regional are committed to present the course this year even though all the topics have not been developed. This is where you come in....

### Your Assistance is Solicited

Here are some questions. The answers you give can aid the Nashoba teachers and it may result in a 9th year science course which you and your school may wish to use.

1. Are the topics listed above, the ones you would choose for these students? Which ones do you think should not be included? What other topics would you suggest?

2. What information do you think should be included in the topics selected?

3. What source materials for students that you would suggest the Nashoba teachers examine? (Keep in mind the question of copyright. The materials will be have to be reproduced without too much difficulty.)

4. Are there any demonstrations, laboratory activities, role playing activities, stimulating discussion topics that you can suggest that could be included in the study of any of these topics?

5. Do you have any general comments to make about the plan?

**A Note About This Project**

It is generally acknowledged that teachers are the best innovators of classroom materials. Here is an opportunity for all of us to collectively help produce a new course of studies which will aid students to better understand their world and be better prepared to act intelligently to preserve the Earth.

The suggestions you make and the on-going development of the material will be published in future issues.

Please mail your answers, suggestions and comments to;
Nashoba Project,
Climate Protection Institute,
5833 Balmoral Drive, Oakland, CA 94619

### Out of the Pool Free Information

Under the direction of Bryan Gosling, Public Relations Manager of New York Power Pool, a resource for communicators called *Dialog - Global Warming* is offered free of charge. It is an information clearing house service providing copies of articles, reports and newspaper stories related to global warming.

To receive *Dialog - Global Warming* contact New York Power Pool, 3890 Carman Road, Schenectady, NY 12303 (513) 381-2238

### Leadership Development Program for Science Leaders and Leaders-to-be

The National Science Supervisors Association (NSSA) recognized that effective science programs need skilled leaders. It has established the first national center committed to science leadership development. The Leadership Institute for Science Education Center (LISE Center) was opened this past July. It is located on the campus of Central Connecticut State University, New Britain, CT.

Under the direction of Dr. Kenneth R. Roy, executive director of NSSA, the LISE Center will help science supervisors become more effective advocates for quality science programs. It will provide programs and resources to develop leadership skills, facilitate communications among science supervisors and promote collaborative pilot programs for the education of science supervisors at the university level. In addition, the LISE Center will develop programs for aspiring, neophyte and veteran women and minorities in science leadership roles.

NSSA members will receive a calendar of leadership training programs and lists of resources through the publication of LISE LETTER. For additional information contact:
Dr. Kenneth R. Roy
National Director
NSSA/LISE, Copernicus Hall (Room 227), CCSU, 1615 Stanley Street, New Britain, CT 06050 (203) 827-7981

## An STS Educator Speaks About Americans and Global Climate Change

by Nancy Van Vranken

Why is it that even the well-educated American citizen finds it so difficult to deal with the concept of a global climate problem? What makes this problem different from the myriad of others that confront us daily ? We seem to be able to cope with topics such as dirty waterways and beaches. Indoor pollution does not panic us. Even an occasional nuclear disaster does not seem to cause more than momentary stress. Why is this unlike the others?

Perhaps one reason is that Americans have always been a nation on the move. If we don't like the conditions in one area, we can always escape to another . For several years the news has been telling us that we can't swim in or drink the water. That's been no big deal. We can build swimming pools and filter our water. There has always existed a technological "quick fix." Now, however, we are being told that the whole world is going to warm up and we're either going to drown in our coastal cities or dry up in the midsections of the country. All of a sudden we've lost our options. The "quick fix" has vanished.

Even the U.S.. government in which most of us have had more faith than we wish to admit, can't solve the problem for us. We are suddenly related to the rest of the world and to make matters worse, have been told that we are a major source of the problem.

Americans also are used to having their problems clearly defined and short term. Climate change, however, is only being predicted by scientists and the real consequences may be decades away.

"You can't fool Mother Nature" is an adage that most of us have chuckled over. Now few are laughing. Reluctantly we are learning that the earth is a cybernetic system with all the feedback loops inherent in such a system. It's been functioning for eons much like our household thermostat which is one of the few appliances that rarely breaks down. All of a sudden it is beginning to fail and the repairmen are saying "When I can get to you a month from next Tuesday, I'm sure any model which will solve the problem is not going to work with the overload on your current system." Our reaction as Americans is to say, "what overload"?

Every labor-saving device known to man is now advertised as a "must have" on the tube. Imagine life without a toaster, microwave, electric can-opener, washing machine, dryer, dishwasher, vacuum cleaner, T.V., stereo, V.C.R.. -not to mention at least one car. How can one survive in the suburbs without a lawnmower, hedge trimmer, power saw, fireplace and barbecue grill--not to mention two cars? These are amenities of modern society, not "overload."

We are beginning to accept the fact that our society is part of the problem, but if this is true , we want to be in charge of the solution.

This perhaps is the first time in American history that the solution is out of our hands. The theme song of America is "independence." Now we are being forced to realize that "interdependence" is the watchword. We want to keep all the amenities that we have but we are willing to bend a little as long as others will follow suit.

The developing countries, however are insisting on being allowed to develop and want no part of any international cut-backs. They want washing machines, cars, stoves and stereos. We've always believed in international cooperation as long as everyone else was willing to cooperate on our terms, but now a large part of the world is refusing.

This problem is very different. Its immensity alone has us overwhelmed. We cannot escape. We cannot call the repairman and we cannot handle it alone. We have to become part of a global project and for the first time in our short history realize that we are citizens not only of our own country, but also of the world.

Nancy Van Vranken teaches at St. Bernard's School, New York and with Irma Jarcho and John Roeder is a founder of the Teachers Clearinghouse for Science and Society Education.

# An STS Lesson on Global Warming

by John Roeder

The issue of global warming has been transformed from one of concern to a small group of scientists to a item on the agenda of world leaders. It has been transformed from an issue we will have to deal with someday to one to be concerned about now. Global climate change has moved onto the front pages of the world's newspapers and into the awareness of today's students.

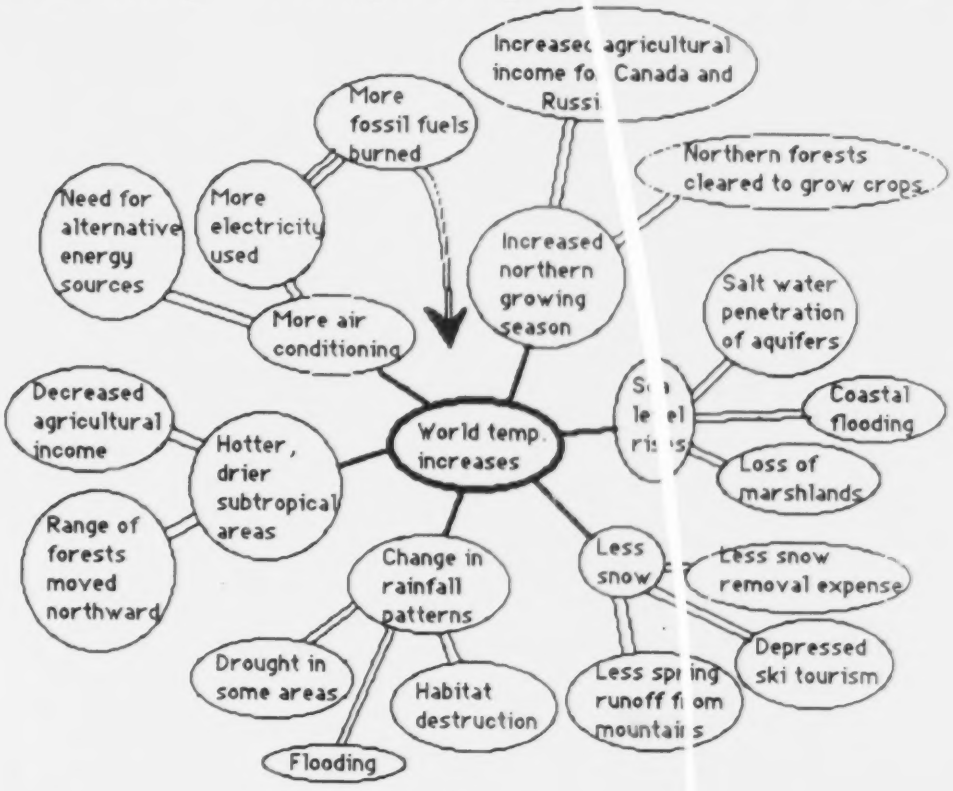
Science Technology and Society educators have seized upon global warming as a primary STS topic. And indeed it is. Understanding the mechanism of the warming itself is science, responding to it will undoubtedly require technology, and the very nature of a response involves society.

Among the many classroom activities that can be focused on global warming, I would like to suggest the technique of the Futures Wheel. This technique has been traced back to the Acid Rain Foundation, which is one of the recent entrants developing curricula on global climate change. It involves starting with a "what if ...?" and responding with as many consequences as possible. These are arranged around the original "what if" and connected to it like spokes of a wheel. These primary consequences themselves have secondary consequences, which are then linked to the primary consequences by a double spoke, etc.

Suppose you take for your "what if" the following: What if the Earth's temperature increased the 3° C predicted by doubling the atmosphere's carbon dioxide? The vast number of consequences was thrust upon me by reading the Executive Summary of the EPA Draft Report to Congress, "The Potential Effects of Global Climate Change on the U.S." (Oct., 1988)

The futures wheel I came up with is depicted in the accompanying diagram, and I'm planning to ask my students to do one. It's a really exciting group activity requiring a great deal of thought about the many interrelationships in our lives. I hope you will give it a try with your students, too.

John Roeder, The Calhoun School, N. Y. is the editor-in-chief of the free:
Teachers Clearinghouse for Science and Society Education Newsletter
c/o New Walden-Lincoln School, 1 West 88th Street
New York, NY 10024



## Suggested Student Activities

√ Put the following well-known quotation from John Donne on the board and ask the students to write a paraphase or describe what it means to them.

Ask them why the quotation is truer now than it was when Donne wrote it in 1633.

"No man is an island, entire of itself; every man is a piece of the continent, a part of the main .... Any man's death diminishes me, because I am involved in mankind; and therefore never send to know for whom the bell tolls; it tolls for thee."

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√ Ask your students to write a "description" of their weekend assuming that the supply of electricity was cut off for the whole town at 3:00 PM Friday afternoon and was not restored until Monday morning. What effects would such a situation have on the community? Discuss in what ways electricity performs vital functions and in what ways is it used unnecessarily?

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√ Have your students make two lists: NEEDS and WANTS. In the first column ask them to put the items they think are the basic needs of every human being for a decent life. In the second column have them list the items that they would find necessary to give them a lifestyle that they would like for themselves or for their children.

Discuss the global environmental impact if all people had the all the items in the WANTS column. Continue the discussion with the question, "Do all people have the right to the kind of lifestyle the WANTS column describes?" What do we do if the answer is "Yes"?

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√ Have your students design a quiz for another class or for their parents on the subject of the reasons for the deterioration of the global environment. Include questions on who is responsible.

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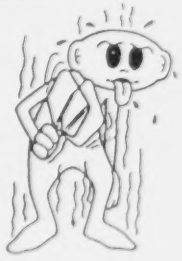
√ Researchers at the World Resources Institute in Washington have predicted an increase in days above 100° F by the middle of the next century if current rates of greenhouse gas emissions is maintained. The list below shows the possible changes for selected cities.

Have your students determine the average number of days per year with temperatures above 100° F in your locality using the last 5 years of weather information.



Ask them to interview residents, businessmen and community leaders to find out what effects would be expected if the number of "scorchers" rose by a factor between 7 and 12.

| Days above 100°F | from | to |
|---|---|---|
| Washington, D.C | 1 day | 12 |
| Omaha | 3 | 21 |
| New York | 0 | 4 |
| Chicago | 0 | 6 |
| Denver | 0 | 16 |
| Memphis | 4 | 42 |
| Dallas | 19 | 78 |

## A Visit from Tokyo TV

The *Greenhouse Gas-ette* has evidently found its way into strange places. Over the past three years we have gotten somewhat used to letters from far away places; Chile, Iran, Poland and Australia are examples. During the summer we received a call from Tokyo that was rather unusual. Tomio Shimoyama of NHK, the national broadcasting corporation of Japan, called to ask for information about our organization. He said his assignment was to video tape examples of non-governmental response to the problem of global warming in the United States.

Three weeks later we had the film crew in our office and the following day they taped a group of students at the Lawrence Hall of Science at the University of California, Berkeley measuring the amount of carbon dioxide emitted from various sources. (See our article in *The Science Teacher*, May, 1989.)

Some weeks later, after school had begun, another NHK recording crew returned to video tape a high school class at the Head-Royce School in Oakland doing our role-playing activity "World Conference on the Reduction of Greenhouse Gas Emissions".

The program will be shown nation-wide in Japan in October. Mr. Shimoyama says that he expects to receive many telephone calls after the broadcast from Japanese educators for details. He hopes the airing will stimulate Japanese educators to bring the subject of global warming into their classrooms. We've agreed to supply copies of the *Greenhouse Gas-ette* to any organization which will translate and publish them for Japanese educators.

## Science Note

### Increased Cloudiness - Will it cool us off? or blanket us in?

Clouds are the window shades of the world. They normally cover about half the Earth. They are the most distinctive feature of our planet when it is viewed from space because they reflect such a large part of the incoming solar radiation. The Earth's reflectivity (albedo) is about twice what it would be without its cloud cover. Clouds thus serve to cool the Earth.

But clouds also absorb the long-wave (infrared) radiation which is emitted from the Earth's surface, they re-radiate it and thus retain the heat below them. This makes the Earth warmer. Which then will it be? The expected increase in average global temperatures brought on by increases in greenhouse gases will increase evaporation. Will the additional clouds cool us off or contribute to our overheating?

Recent measurements by satellites have increased our knowledge of the effect of clouds on our climate and the news, so far, seems good. The initial results show that clouds reflect more energy than they absorb. The data from April, 1985 show that clouds around the globe reflected 44.5 watts per square meter into to space while they held back 31.3 watts per square meter of Earth's infrared radiation. The net result was a reduction in heating of the Earth by 13.2 watts per square meter. [1]

The role of clouds has long plagued the computer modelers who try to predict our future climate. They have estimated that a net heat increase of only 4 watts per square meter from a doubling of the $CO_2$ will warm the Earth 2.8° to 5.2° C in the next century.

This latest study suggests that the net cloud cooling effect is about from three to four times greater than the predicted doubled $CO_2$ warming effect. A small change in cloud cover can play a significant role in a negative climate feedback mechanism.[2]

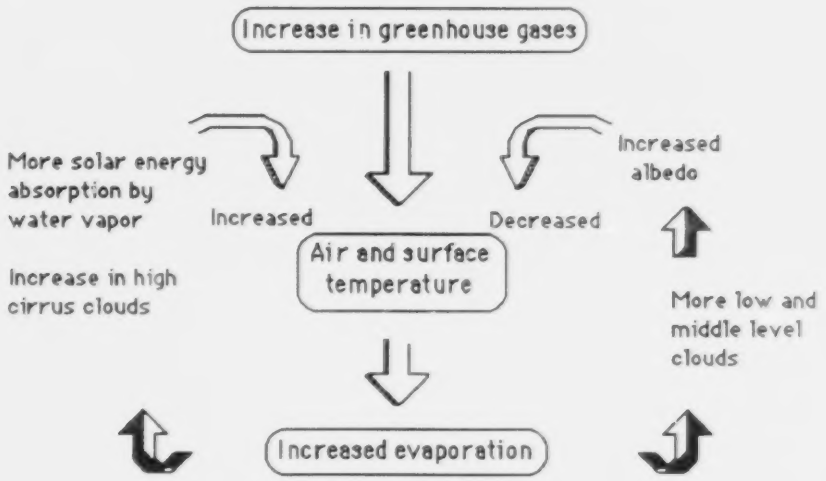
Don't breathe too great a sigh of relief. Many unknowns still exist. Increased cloud cover can be expected as we change the atmosphere by increasing the concentration of greenhouse gases, but what kind of clouds will they be? Low and middle clouds reflect more solar energy back to space than the energy they absorb from the ground. High, cirrus-type clouds trap significantly more infrared radiation than their lower cousins. The final result of increased cloud cover is still unclear.

It is also unclear how the increase in humidity in a warmer atmosphere will affect world climate. Water vapor itself acts as a greenhouse gas.

[1] R. Kerr; How to Fix the Clouds in Greenhouse Models, *Science*, Jan. 6, 1989

[2] V. Ramanathan, etal., Cloud-Radiative Forcing and Climate, *Science*, Jan. 6, 1989

Cloud Feedback Mechanisms



## New References

### A special issue of Scientific American

September is a special month. For many of us it is the beginning of the year. For the publishers of *Scientific American* it is the month of the special issue. To their credit, the board of editors chose Managing Planet Earth as the theme for this September.

This issue of the magazine could serve as a text on global environmental issues. There are 11 articles that detail the relationships between human society and our mother planet.

The articles, *The Changing Atmosphere* and *The Changing Climate*, are particularly good summaries of our current position. *Threats to Biodiversity* and *The Growing Human Population* expand on the dangers we are facing.

The four articles that follow them are devoted to strategies for mitigation of our global environmental impact. The concluding article written by William Ruckelshaus, *Toward a Sustainable World*, describes the steps we need to take in order to reach that essential goal.

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### Scientific American - again

The lead article in the April, 1989 issue is *Global Climate Change*. It is an excellent sumary article for your advanced students.

There is a good diagram of annual carbon fluxes (on page 38) and there are many useful graphs.

### Two articles in The Science Teacher

Key areas for the study of global climate change are those in the high latitudes. It is there that climate modelers predict the larger temperature rises will occur. Information about sea ice, snow, glaciers and ice sheets and their relationship to global warming is included in the article *Global Climate Change* by Dorothy K. Hall which appears in the September, '89 issue of *The Science Teacher*.

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A laboratory activity in which students measure the amounts of CO2 from various sources by dissolving gas samples in bromthymol blue solution and titrating with dilute ammonia is described in *The Greenhouse Effect in aVial* by Richard Golden and Cary Sneider in *The Science Teacher*, May, 1989.

### The Burning Question a unit for 5th and 6th grades

This 4 session unit is available from CPI.

Outline

1. The process of burning and its products.
2. Burning supplies us with energy and produces carbon dioxide
3. Respiration is a kind of burning
4. The carbon cycle
5. The relationship between carbon dioxide and the greenhouse effect
6. What individuals can do to reduce the emission of carbon dioxide.

Please mail $3.00 to the address below. Feel free to reproduce the unit for your colleagues.

The Burning Question - CPI
5833 Balmoral Drive
Oakland, CA 94619

### A new book on global warming

Stephen Schneider is one of the scientific community's most outstanding communicators on the topic of global warming. In his books, articles and television appearances he has cogently presented the latest scientific information and the policy options open to us. His latest book *Global Warming: Are We Entering The Greenhouse Century ?* Sierra Club Books, distributed by Random House, 1989 is a welcome addition to the literature.

Besides the question of the title the author discusses other questions. In the absence of scientific certainty is it wise to act? or shall we wait? How shall a public informed by the simplifications of 30 second TV tidbits form an intelligent basis for sound judgement? These are only a few of the topics which occupy his attention.

For an intelligent guide through the intricacies of global climate change and its interrelationship with living organisms, human and otherwise, this and the author's other books are recommended.

See: *The Genesis Strategy*, Plenum Press, New York, 1976
*The Coevolution of Climate and Life*, (with Randi Londer) Sierra Club Books, San Francisco, 1984

## Science Note

### The Fertilization Effect - from a definite plus to a definite maybe

Carbon dioxide is good for plants. Will more carbon dioxide be better? Under the modern axiom that "Nothing succeeds like excess" one would expect plants to love global warming. Indeed, there is experimental evidence that plants significantly increase their photosynthetic activity when the carbon dioxide content of the air is increased. Some plants translate this into increased growth and crop yield. The doubling of the present atmospheric carbon dioxide concentration has been predicted to lead to a 0 to 10% increase in C4 crops (such as maize and sugarcane) and a 10 to 50% increase for C3 crops (such as wheat, soybean and rice) [1].

These predictions, which were based on admittedly limited experimental results, are now being called into question.

Increased carbon dioxide can only be considered a mixed blessing to plants according to the work reported at the American Institute of Biological Sciences in Toronto in August. Sugar maple trees, for example, did not benefit from increased carbon dioxide.

For the first time, precise measurements were taken of the carbon dioxide released by roots. It was found that five times more carbon dioxide is released underground by roots than by the leaves of a plant. Sugar maples increased their underground carbon dioxide "exhalations" under conditions of carbon dioxide enrichment and they did not grow any faster than trees under ambient carbon dioxide levels. However, beech trees, it was reported, did grow faster with more carbon dioxide in the air. [2]

Another group reported that the expected increase in ultraviolet radiations due to the depletion of the ozone layer, which they simulated in their experiments, causes a reduction in photosynthesis of 5 to 10%. When plants were subjected to a combination of both the UV increase and the carbon dioxide increase their rates of photosynthesis increased but to a lesser extent than those grown without the exposure to UV radiation.

[1] Carbon dioxide, Climate Change and Agriculture, Warrick, R. A., etal. in *The Greenhouse Effect, Climate Change and Ecosystems*, SCOPE 29, John Wiley, 1986
[2] Not all plants will thrive in 'greenhouse', *Science News*, August 26, 1989

## Taking from the Commons - a lesson in self restraint

### Prologue to the lesson

In a now classic essay, "The Tragedy of the Commons" published in *Science* Dec. 13, 1968, Garrett Hardin pointed out in modern terms what Aristotle said long ago, "What is common to the greatest number gets the least amount of care." The situation is tragic when men of good will, acting rationally, harm themselves and others.

In times when communities put parcels of pasture land aside for common use, farmers rationally seeking to increase the size of their herds, put as many cattle as they could on the public land. The commons being a finite resource would eventually reach its carrying capacity and the addition of only a few more cattle caused the land to deteriorate. The resource on which all depended was destroyed although no man sought to do evil.

**Exploitation of common property resources leads to mutual ecological ruin**

Unfortunately the atmosphere, like the land, waterways and oceans, have been treated for millennia like common property resources. We are learning, to our dismay, that there is only one ecological commons, that its carrying capacity is being reached and in many ways has already been exceeded.

Factory owners and we, automobile owners and energy users, think nothing of dumping our gaseous wastes into the common atmosphere. We have ignored its finite carrying capacity and relied upon the wind to take our wastes "away." We are learning that "away" is our neighbor's air and that we all share it.

This mutual ecological ruin is the modern "tragedy of the commons."

(for more information on this and related topics see:
*Ecology and the Politics of Scarcity* by William Ophuls, W.H. Freeman & Co., 1977)

## Taking from the Commons - a Simulation Game

***"There's a way to play in which everyone wins."***

### The Game

The game is played by groups of 10 - 12 students. They sit on the floor in a circle around a container in which you have put 30 tokens. Poker chips are good.

Explain the following rules to the students and allow for questions so that you can be sure everyone understands. Assure the other groups that they will have their turns to play.

- The tokens are in the "common space."

- Everyone may take tokens away from the common space.

- 10 tokens may be traded in for something of value which you select. Make it something that cannot be shared; like being excused from an assignment or a quiz.

- A student may not win more than one prize. (10 tokens are all that are needed.)

- The game is a series of rounds which end after 30 seconds of play or when the commons is empty, which ever comes first.

- Explain that at the end of each 30 second round you will count the number of tokens left in the commons and put in an equal number to replenish the supply. The total at any time may never exceed the original 30.

If there are no tokens left and no replenishment is possible, then the game for that group is over. Another group takes its place.

- There is no talking among the participants.

At "go" there will be a mad scramble. It is likely that the commons will be empty before 30 seconds are up. If so, observe aloud that there are none left and therefore there can be no replacements. The game is over for this group. Are there winners? Did they take more than 10 tokens? Were there bruised losers? Have them return the tokens to the common pool.

### A change of rules Everybody wins

Let the other groups have their turns to play without commenting further. When all have had a chance let the first group return to play again. Announce the change of rules. They may now speak to each other and the second group will play with whatever tokens are left when the first group is done.

Encourage them to discuss the game before it begins. Tell them,**"There is a way to play this game so that everyone can be a winner."** See if they can generate a cooperative strategy based on self restraint.

To some students it will become obvious that if they each take only a few tokens the remainder will be counted by you after 30 seconds and you, by the rules of the game, will replace tokens equal to the number left in the commons.

They then will be able to take a few more in the next 30 second round. Thus, in a few rounds they each can achieve the full amount to "win."

After the play if they did not leave any tokens for the next group, point out that they have prevented others (the next generation) from playing.

### Discussion

In a guided discussion develop how, in the long run, more can benefit if the individual restrains from taking too much. Let them recognize that attitudes of cooperation, of respect for nature, will achieve the goal of the greatest benefit for all.

Suppose the tokens were trees, or fish in the ocean, or pasture land, or water, or portions of the air we all breath. Restrained use would allow nature a chance to replenish the renewable natural resources that would make everybody, including future generations, winners.

Point out that selfishness and greed (on the part of those who took more that 10 tokens) leads to pain and deprivation to others. End the game by saying, "I think you know that what we have just experienced is more than a game."

If things go well, there may be a moment of silence in which a lot of thinking and learning is done. It may even happen that one will claim the prizes.

**Note:** This game is adapted from Thinking Globally and Acting Locally, L. Mann &W. Stapp, editors ERIC -Clearinghouse for Science, Math and Environmental Education, Ohio State University, 1982 Original developers:
Kurt Frischknecht, Ursula Frischknecht and Karen Zimbelman; Univ. of Michigan

**"It is better to exercise restraint than it is to exploit renewable resources."**

# A Lesson on Human Activity and Methane Production

Methane, our most abundant hydrocarbon often called natural gas, is a very efficient absorber of infrared radiation. Although its present atmospheric concentration is only 1.68 parts per million, its high rate of increase is a cause of concern.

If, as expected, the atmospheric concentration of methane doubles in the next 30 years, the cumulative warming effect of methane and the other trace greenhouse gases will equal that of carbon dioxide alone.

Ice bubble analysis has shown that methane concentration held steady for the last 10,000 years. About 300 years ago the level began to rise and 100 years ago it began to soar. The current rate of increase of methane (1%) is greater than that of carbon dioxide (0.4%).

There is no clear consensus among scientist of why the concentration of methane is rising so rapidly. Most of it comes from the breakdown of plant material in the absence of oxygen, as in swamps inside cattle and the heating of plant material underground.

>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Below are a collection of facts about methane production and a series of questions for your students.

Methane fact:
Cattle belch at the rate of about twice a minute. The result is about a 1/2 pound of methane put into the atmosphere each day by each cow.
Question:
How much methane is in each cow's belch?

Methane fact:
The natural gas that we burn in our homes and in bunsen burners is about 90% methane.
Question:
Is methane lighter or heavier than air? What do you think happens to the gas which escapes and is not burned at the stove?

Methane fact:
Rice plants are hollow tubes that are growing in waterlogged soil. Methane produced by bacteria in the muck finds it way into the atmosphere through the rice tubes.
Question:
Have you ever seen bubbles rising from the muddy bottom of a lake? What could the gas be and where do you think it came from?

Methane fact:
A methane molecule is composed of 1 atom of carbon surrounded by 4 atoms of hydrogen. When it burns it combines with 2 molecules of oxygen.
Question:
What products are formed when methane burns?
[$CH_4 + 2O_2 \Rightarrow 2H_2O + CO_2$]

Methane fact:
The tundra permafrosts and ocean sediments contain vast quantities of clathrates - ice/methane mixtures.
Question:
What may happen if, partly due to the increase in atmospheric methane, the clathrates melt?
How does the term "positive feedback mechanism" apply to this?

Methane fact:
Below is a list of sources of methane in order of volume produced - highest to lowest.

- Wetlands, swamps
- Cattle
- Rice paddies
- Tropical rainforest and grass savanna burning
- Natural gas and from mines
- Man-made dumps, landfills
- Termites and other insects
- Oceans
- Lakes
- Tundra

Question:
Which of the sources of methane above can be traced to human activities and human population growth? Explain your selections.

**Comparing human population growth and methane production**

On the reverse side of this page is a graph of human population growth. The left hand side is labeled Methane concentration parts per million but no methane information is on the graph.

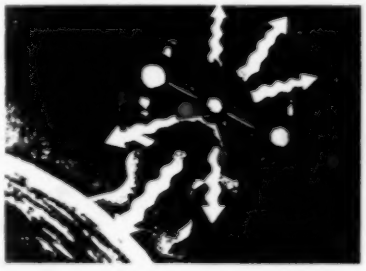
Reproduce the graph and have your students spot in the experimental evidence listed below. Readings prior to 1979 were obtained from bubbles caught in glacial ice.

| Year | ppm | Year | ppm |
|---|---|---|---|
| 1500 | 0.64 | 1870 | 0.84 |
| 1530 | 0.72 | 1879 | 0.86 |
| 1590 | 0.66 | 1915 | 0.95 |
| 1620 | 0.68 | 1950 | 1.15 |
| 1670 | 0.65 | 1970 | 1.30 |
| 1715 | 0.72 | 1979 | 1.54 |
| 1750 | 0.70 | 1983 | 1.60 |
| 1790 | 0.78 | 1984 | 1.63 |
| 1820 | 0.76 | 1986 | 1.65 |
| 1850 | 0.80 | 1988 | 1.68 |

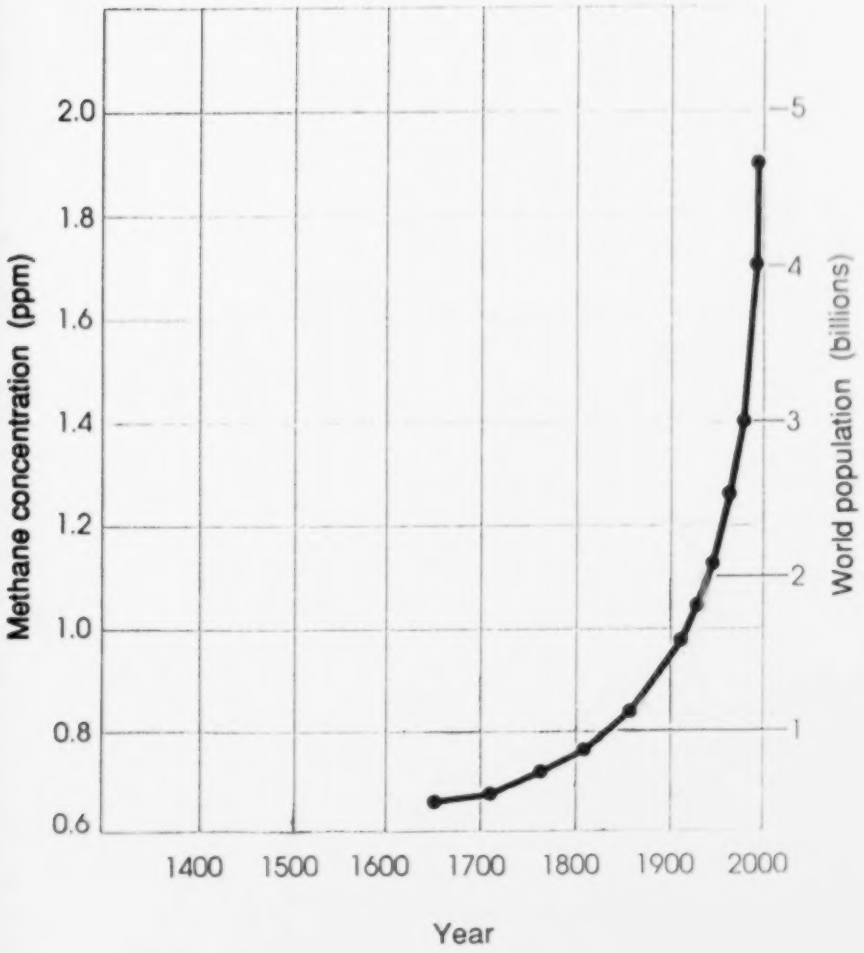
Follow up questions:
1. Using the overlaying graphs how does the growth in human population compare with the increase in concentration of methane in the atmosphere?

2. How can you explain the relationship that the two graphs seem to show? Refer to the human activities that produce methane.

3. Based on the information in the graphs what would predict for the year 2050?



## Human Population and Methane Production






See page 11

### In this issue


- Global climate as an STS topic ..... Page 1
- Help develop a new science course ..... 1
- About Americans and Global Climate Change ..... 4
- Futures wheel lesson ..... 5
- Suggested student activities ..... 6
- Science note on clouds ..... 7
- "Taking from the Commons" lesson ..... 8
- Human Activities and methane production lesson ..... 11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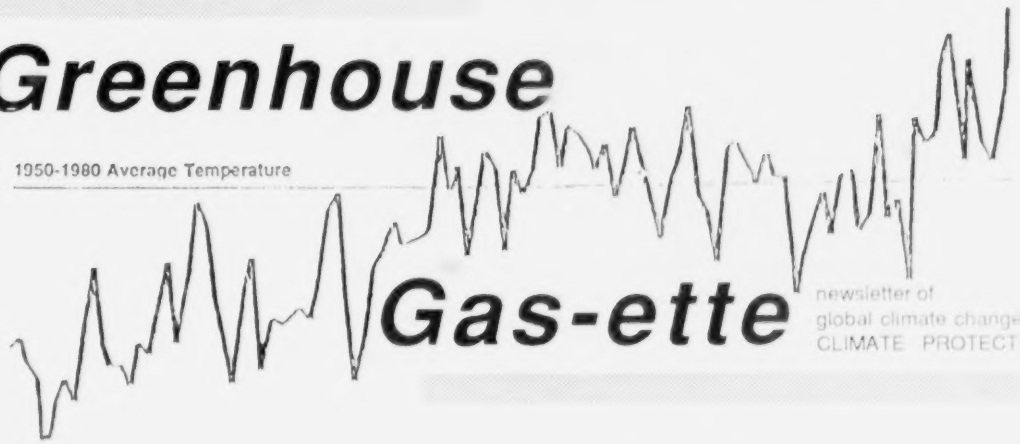
*"The amount and rate of climate change depend on how people behave."*
Dr. Stephen Schneider

# Greenhouse Gas-ette

Winter 1990

newsletter of global climate change education
CLIMATE PROTECTION INSTITUTE


## The Tragedy of the Greenhouse Effect

### When reasonable actions produce bad effects

To call global climate change a tragedy is, perhaps, to state the obvious. Climate changes in the human communty and changes that hurry species to extinction are indeed tragic. It is always a tragedy when the innocent suffer because of the ignorance or apathy of others. But the increased greenhouse effect is also a tragedy in the sense that Garrett Hardin used the term in his famous essay, "The Tragedy of the Commons" which appeared in Science, December 13, 1968.

### The remorseless working of things

Hardin uses philosopher Alfred North Whitehead's definition of tragedy as "the remorseless working of things." He sees well-meaning, rational people acting in ways that seemed innocent but which result inevitably in death and destruction.

The thesis of Garrett Hardin's paper is that certain problems of the world have no technical solution and can only be solved by fundamental change in human values. While his essay, "The Tragedy of the Commons," is centered on the problem of increased human population and its effect on the environment, the analogy it presents can also refer to the prospect of global climate change.

### Once upon a time ...

in many English villages, so Hardin begins, there were pasture lands available to all herdsmen. These lands were properties held in common by all the citizens and they were set aside for common use. (The park called the Boston Commons is a vestige of this idea.) Each well-meaning, rational herdsman sought to maximize his use of the commons for the benefit of his family and himself and therefore he would put as many cattle as he could on the common pasture. Once there, his cattle would consume the resource of grass which was the property of all the citizens for his, the herdsman's, private benefit.

Even if the herdsman was educated and far sighted and recognized that the long-term result of his and his neighbors actions meant the destruction of the common pasture, he would do it. (Therein lies the tragedy.) For, even if he refrained from exploiting the common resource, surely his neighbors would not, and they would think him a fool to lose out on the short-term gains they were enjoying.

### "That which is owned by all, is cared for by no one"

These words of Aristotle forecast the way we have treated our streams and rivers. The oceans of the world are currently being treated as commons. They are dumped into without hindrance and their resources of fish and whales are being shamelessly exploited.

The Earth's atmosphere is another of humanity's commons, and the various nations are the users of that commons. Each user attempts to maximize its use for the benefit of its own family, its nationals. In that pursuit nations are wearing out the common resource of the established atmosphere. Modern industrial countries seem to count it a "right" to exhaust their gaseous waste products into the common atmosphere. Consider what the reaction in our country would be if, Brazil say, would propose that we reduce our energy use and our propensity for automobile travel so that the amount of carbon dioxide we put into the global atmosphere would be decreased.

## The Tragedy of the Greenhouse Effect

(continued from page 1)

The same sort of actions are evident on the corporate and individual level. Practices established when the air, oceans and land were conceived as resources so vast that they could not be affected by human activities are now being continued by company and individual alike. The fact that individuals see the discontinuance of their abuse of the commons as too costly to them for the benefit which will accrue to all in the future, must be realistically faced if we are going to make any headway on the problem of global warming.

**The immediate cost to the individual seems to outweigh the long term benefit to the environment**

It is the old argument over the choice between the greater though distance good and the more present lesser good. This choice is made more difficult because the distant good, a viable global environment, is shared by all and the individual or corporation is called upon to sacrifice some private benefit for that greater good. The proportionate share of good received looks too small in comparison to the cost.

This, then, is the problem which cannot be overlooked in our efforts to reduce the threat of global warming. It is a problem of human nature and human values. In the absence of a change in human values, legislation or taxation may be necessary to reduce the excessive abuse of our common atmosphere. To those who see such restrictions as a curtailment of their freedom of action, Garrett Hardin would reply, a person never has the right to bring on universal ruin.

Perhaps the most crucial challenge that global environment educators face, is how to address the reality of this situation and assist students to acquire the practice of thoughtfully weighing present actions in terms of future consequences.

Constructing lessons that exemplify this procedure is difficult. Some possible beginnings are listed below. If you have any suggestions on how to turn them, or others, into lessons please send them in.

### Lesson beginnings

**The student** "If I drive every day to school or to work, the amount that my car will contribute to the overall increase in carbon dioxide is infinitesimal. The effort I will have to put in to ride a bicycle, or get to the bus stop is considerable. Why should I change my practice of car use?"

**The entrepreneur** "I am an environmentally sensitive factory owner making widgets and I need some advice from high school students who are my best customers. I know that greenhouse gases are produced from the operation of my factory. I want to reduce them. The installation of expensive pollution control equipment will prevent my manufacturing operation from harming the atmosphere but I will have to add $2.00 to the price of my widgets. To tell the truth, my widgets, which you by in large numbers, are really identical to those that my competitors manufacture. You can buy them from him just as easily. Will you buy *my* widgets if I install the pollution control equipment and then my widgets cost more than my competitor's?"

**The politician** "My country is just beginning to develop its industry. My fellow countrymen have been living a poor existence without the benefits which you, in your country, take for granted. Now we have electricity and we are beginning to build roads which will carry the new automobiles that our people can now afford. You say that the atmosphere has too much carbon dioxide and that we should not increase it. But the air belongs to us just as it much as it does to you. If, to make a better life for our people, we must dump carbon dioxide into the air, just as you did, why should we not?"

### Team teaching possibility

Parts of the Tragedy of the Commons problem are well suited to the social studies classroom. Here is an opportunity for creative team teaching. Present the problem to a social studies colleague and see if two disciplines can combine to prepare your students to act to preserve our global commons.

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## Nashoba Project Report

Our last newsletter explained that teachers at Nashoba Regional H. S. in Bolton, MA were developing a new general science course for their 9th graders. The focus of the course is on science related issues important to civilization. Of course, among them is the problem of global climate change.

Sue Vogel, Science Dept. Head, reports that the 4 teachers that are teaching the course at first feared that they would not have enough material but now they have all they need. Part of the reason for that may be the efforts of some of our readers who generously contributed suggestions and materials.

Among them were:
Carol Airasian - Boston, MA
Bob Boekelheide - Wapato, WA
Carole Kuchinsky - Phila., PA
Constance Lemke - Orlando, FL
Scott Lewellen - Bemus Pt., NY
Elma May Page - Wilm., DE
John L. Roeder - New York, NY
Tom Wellnitz - Beverly, MA
Many thanks!

## Earth Day 1990

A committee of about 20 teachers from the San Francisco School District have been meeting to plan for the participation of students in activities related to Earth Day, 1990 (April 22). They were pleasantly surprised when the school board extended the period of district participation to a full week. The committee is preparing a Pre-Earth Day Fair on a Saturday in early March. At the Fair teachers will be shown hands-on activities for their students. Local environmental organizations have agreed to participate. A local museum has offered facilities for theFair.

A representative of the local electric utility company, PG & E, is on the committee and she agreed to make their activities on energy conservation available to the teachers at the Fair.

One of the activities suggested is the organization by students of a Earth Day Pledge Drive. A document has been devised which is reproduced on page 11.

EARTH PLEDGE
I PLEDGE ALLEGIANCE TO THE EARTH
AND ALL ITS SACRED PARTS,
ITS WATER, LAND AND LIVING THINGS
AND ALL ITS HUMAN HEARTS.
I PLEDGE ALLEGIANCE TO ALL LIFE
AND PROMISE I SHALL CARE
TO LOVE AND CHERISH ALL ITS GIFTS
WITH PEOPLE EVERYWHERE.
Global Education Associates

A national office exists. It can be contacted at
EARTH DAY - 1990
P.O. Box AA
Stanford, CA 94305
(415) 321-1990.

## Suggestions for Independent Projects

• Stimulation of "trigger hairs" are necessary to cause a Venus fly-trap to close. Do the number of stimulations vary with temperature? Are there temperatures at which the trap will not close?

• Discover the growth temperature range of duckweed, algae or bacteria. What are the optimal temperatures for their growth? What might be the result of warmer climate conditions.

• By charts and diagrams show the relationship of winter snow pack in the mountains to water availability during the summer. Show what would happen if the climate warmed and there was rain and not snow in the mountains during the winter.

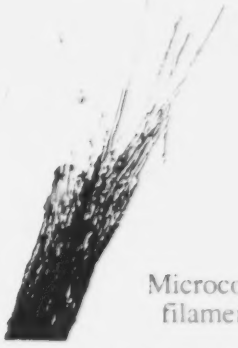
• Make a Methane Gas Fact Display. Include pictures or diagrams of its sources, its uses, and its effect on the Earth when it is in the atmosphere.

• Prepare a conservation and recycling presentation for lower grade level children.

• Make a "Waste Paper Survey" of your school. How much paper is thrown away each day? Do different classes generate different amounts? How much waste is produced for each student in the school? Can careful use make a difference? Record the waste production of a certain class before and after the class agrees to be careful. Publish your findings with a statement explaining why conservation is important.

## Ancient soil microbes may have reduced the greenhouse effect in the distant past

Cryptogamic crust is the name given to the combination of clay, sand, moss, fungi and cyanobacteria that make up the living soil of some harsh environments like Utah's Canyonlands National Park. Cyanobacteria, better known as blue-green algae, are among the oldest forms of life on Earth.



Microcoleus filaments

A recent hypothesis by Tyler Volk of NYU and David Schwartzman of Howard University credits these dark, lumpy clods with transforming the climate of the Earth and permitting it to cool enough to allow more complex forms of land organisms to exist.

A widespread form of cyanobacteria is the genus Microcoleus which grows end to end in clusters of filaments. The filaments are about 5 microns in diameter. The bundles of filaments secrete a sticky polysaccharide to which sand and clay particles adhere. When dried this combination of particles and slime forms into a hard protective sheath. The presence of these sheaths gives stability to arid soil and greatly reduces erosion.

Within seconds after a rainfall these bacteria become active. The filaments that represent their living bodies push out of the hard sheath and, leaving it behind, they grow forward secreting more slime.

By holding the sand and clay particles together the Microcoleus facilitated the formation of soils. The hypothesis contends that these early soils absorbed water that would have normally run off the bare rock surface. The retained water increased the chemical weathering process of the rocks below, and of the small rock chips imbedded in the soil, by 20 to 200 times simply by giving the water and air more time to react with the rock.

It is this chemical weathering which, as part of the long term carbon cycle, removed carbon dioxide from the atmosphere. The authors contend that because of the increase in weathering produced by the Microcoleus stabilized soils, the amount of atmospheric carbon dioxide was reduced and the Earth cooled.
( see: Nature, Aug. 10, 1989 or Science News, Dec. 9, 1989)

*Note for an independent research project*

To test the hypothesis, the scientists are attempting to discover how different microorganisms increase weathering rates. The experimental work is not easy. Perhaps a young scientist might like to tackle the problem of designing such an experiment with suitable controls.

Using pieces of rock and water made acid by carbon dioxide, can a controlled experiment be devised that will demonstrate a difference in the weathering rates due to the presence of living organisms?

## Germinating seeds and carbon dioxide production

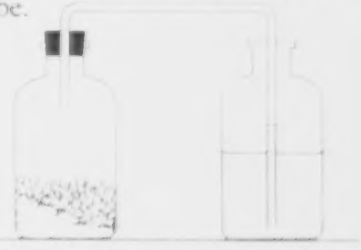
### A student experiment

To measure the amount of carbon dioxide given off by germinating seeds the following procedure is suggested in *A Sourcebook for the Biological Sciences* by Morholt, Brandwein and Joseph.

Put germinating beans or peas on a wad of moist cotton in a bottle or test tube. Connect it with a delivery tube to another container with litmus or bromthymol blue solution. Set the exit of the delivery tube below the solution level.

Calibration marks can be placed on the exit tube with wax pencil. In a few hours the level of liquid in the delivery tube should rise and the solution should turn color, indicating carbonic acid is present.

The volume of carbon dioxide is measured by the rise in liquid level. The carbon dioxide is absorbed into the solution and the decreased pressure in the seed container allows atmospheric pressure to drive the solution up the tube.



A control apparatus should be set up which is identical to the above but with seeds that have been killed by soaking in formalin.

To make the connection with global warming suggest that the students perform the experiment again but with the seed container at higher temperatures. Does the production of carbon dioxide change? Be sure to insulate the absorption container from the temperature change.

# Energy Trapping, Dynamic Equilibrium, and the Greenhouse Effect

**Introduction:**

The following student experiment and teacher demonstration are designed to illustrate some of the principles of energy flow and relate them to the general warming of the Earth's climate due to an increased greenhouse effect.

**Overview:**

The students will record and graph the increase in temperature within a simulated greenhouse. In a guided discussion the principle of conservation of energy is used to help the student arrive at the concept of the equilibrium temperature of a body. The analogy is made that the Earth is such a body.

By means of a teacher demonstration using the flow of water through a perforated container, the idea of dynamic equilibrium is illustrated. A connection is made between closing the openings in the container and the increase in greenhouse gases. The water flow arrangement is used as a model of the dynamic energy flow through the Earth's atmosphere.

**Materials:**

For each team of students:

- a container with a clear top (a shoe box covered with clear plastic wrap, or a clear plastic 2-liter soda bottle laid on its side)
- thermometer and piece of clay for sealing it in place, if necessary
- graph paper
- 100 watt incandescent lamp, if sunlight is not available

For the teacher demonstration

- a clear plastic container (a 2-liter clear plastic soda bottle or similar container with holes spaced vertically in its side)
- tubing
- water flow source and drain
- food color (optional)

Preparation:

Heat a phillips screwdriver, or similar metal rod, and melt a series of holes vertically in the container. Start about a half inch from the bottom and separate them by about an inch until the upper one is an inch or so from the top.

Note to teachers:

We would appreciate your evaluation of this activity.
Are there some additions or changes you would suggest?

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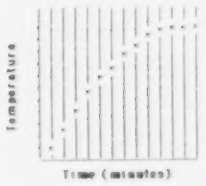
## Procedure 1

### Student experiment:

The students should place the thermometer in their containers so that it can be read without disturbing the closure or the position of the container once the experiment has begun. Close the container and record the temperature within as the initial temperature.

Place the container in the sun, or about 6 inches from an incandescent lamp. Do not disturb it. If sunlight is used, make sure that no shadows will fall on the container in the course of the experimental run (about 20 to 25 minutes). Record the temperature inside the container every minute until there are 3 successive readings that are within 0.5° of each other. Graph the results.

Have the student teams compare their graphs and discuss the results among themselves.




### Discussion and Conclusion:

Either ask the teams the following questions or give written copies to the students for discussion as they compare their results.

1. Why did the temperature inside the container rise?
   (The light energy heated the surface inside the container and the air in contact with those surfaces warmed. Since the heated air could not get out the temperature rose. This is the action of a greenhouse.)

2. Why did some team records show their containers heating faster than others?
   (Some variables are: the area exposed to the light, the type of transparent cover, the size, shape and materials of the containers, and the position of the container relative to the radiant energy source.)

3. Does the container feel warm? Where is this heat going?
   (The exterior of the container is partially warmed by the heat trapped inside. The walls of the container radiate this heat into the room.)

4. What was similar about all of the graphs?
   (They all showed a leveling off of the temperature rise.)

5. Why did the rate of temperature increase level off even though the light energy continued to enter the container?
   (Energy is neither created nor destroyed so the radiant energy that continued to go in had to go somewhere. All physical objects, under constant energy input, eventually arrive at a state in which they radiate just as much energy as they absorb. They arrive at an equilibrium temperature state.

For example, a cold can of soda will absorb heat energy from the room until it reaches the same temperature of the room. At that point the heat from the room continues to enter the can but the can sends the same amount of heat back into the room. The can therefore stays at room temperature. It has reached an equilibrium condition just as the students' experimental container has after it has been in the light for a while. The difference between the can and the transparent container is that the container has arrived at a higher interior temperature because of its radiant energy trapping structure.)

6. What conclusions can you state as a result of your observations?
   (a. The radiant energy was trapped inside the container and converted to heat energy.
   b. The reason the container reached a maximum temperature and stayed there was because, after the container heated up, it sent energy out from its exterior equal to the amount coming in.)

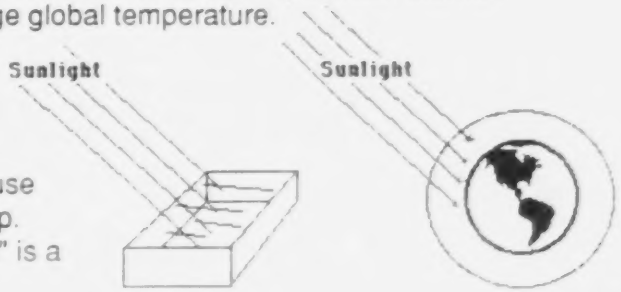
**Note:**

Variations of the student experiment can be performed with different materials on the bottom of the container. If the inside area is large enough, the addition of dark soil will speed the temperature change. Room temperature water on the bottom will slow the rate of temperature change. After the students take their measurements discuss what the results mean with reference to the Earth's surface. The concept of specific heat can be developed.

**Extending the learning - the Earth's greenhouse effect:**

Explain that the Earth, like the transparent container, is a radiant energy trapping structure. The atmosphere lets in the radiant energy of the sun. The Earth gets heated to a relatively high equilibrium temperature because of the heat trapping characteristic of the greenhouse gases in the atmosphere. These gases, (water vapor, carbon dioxide, nitrous oxide, methane, low-level ozone, and chlorofluorocarbons) absorb the infrared radiation which is leaving the Earth and delay its escape into space by re-radiating some of it back to the surface. Eventually the energy sent off into space is equal to the energy received from the sun and the Earth reaches a certain equilibrium thermal condition which is called its average global temperature.

The heat trapping structure of the Earth is different than that of the container. The greenhouse is a convection current heat trap. The Earth's "greenhouse effect" is a radiative phenomenon.



## Procedure 2

### Teacher demonstration:

The purpose of this demonstration and discussion is to solidify the principles illustrated in the experiment and make the connection with the Earth's dynamic energy equilibrium situation and the enhanced greenhouse effect.

[The basis of this demonstration is a suggestion offered by
Dr. Art Sussman, Science Partnership Coordinator, University of California - San Francisco.]

Use the tubing, if necessary, to bring the water into the plastic container with the vertical holes in its side. Ask the students to predict what will happen when you turn the flow of water on.

Demonstrate that the level of water rises until the flow in is equal to the flow out through a number of the holes. (The food color dye can be added to the water to make the level changes more visible.) Ask for a prediction of what will happen if you increase the rate of flow in. Try it.

**Making the connection:**

Suggest to the class that the inflow of water can represent the input of solar energy pouring into the Earth's atmosphere. Ask them, if that were so, what the outflow of water would represent? (The infrared radiation leaving the Earth.)

What does the container represent? (The whole Earth)

What does the level of the water represent? (The average temperature of the Earth)

What will happen if some of the holes were plugged up? (The level of the liquid would rise.)

What does the plugging up of the holes represent on the model of the Earth's energy flow? (An increase in concentration of the greenhouse gases that restrict the flow of energy into space.)

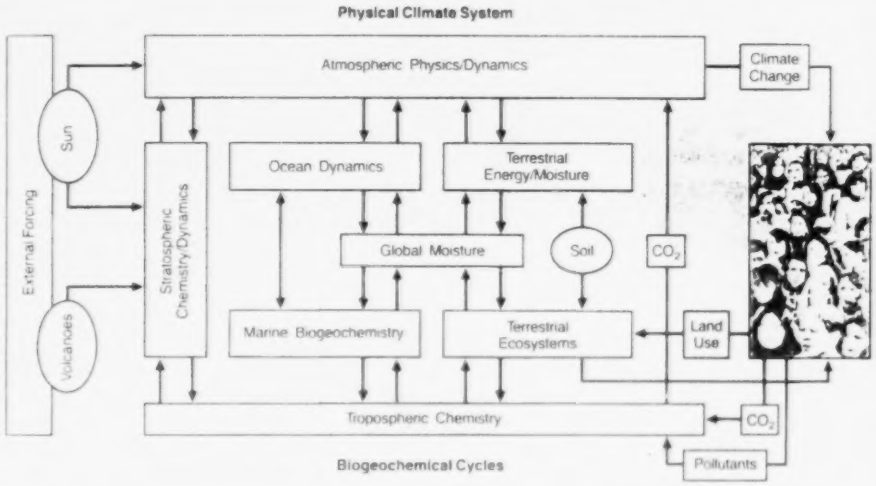
What does the rise in level of the liquid flow model represent on the Earth's energy flow model? (An increase in the average temperature of the Earth. Point out that the situation is one of dynamic equilibrium. The Sun's energy is continuously coming in, and after a certain level of temperature has been reached because of the greenhouse heat trap, the same amount of energy is radiated from the Earth into space. Refer to the student experiment. )

**Summing up:**

Ask the students to explain what an increase in the emission of greenhouse gases means for the Earth. Point out that the increase in emission of greenhouse gases is due to human activities such as deforestation and fossil fuel combustion. Remind the students that their use of energy is part of the problem.

# Revisiting the Water Cycle - the Global Role of Water

It is an odd fact that, despite its obvious importance to human life and its common occurrence, our understanding of the role of water on the planet is meager at best.




Water plays a global role in an enormous variety of Earth system processes. In its liquid and solid forms, for example, water is a powerful agent of topographic change. Entrainment in moving water or ice is the major transport mechanism for rock particles and boulders. This trapped rock greatly increases the eroding action of the moving ice or water. The sediments deposited by rivers over geological time creates new topography.

Water is a solvent in many of the chemical reactions that weather rock and it acts as a mechanical agent in breaking rock through freeze-thaw cycles.

The hydrological cycle plays a major role in climate regulation. It moves both water and heat from the ocean surface into the atmosphere and from the tropics poleward. The net effect is to cool the tropics, warm the more poleward regions and supply water inland, making climate more temperate throughout. The cycle is completed as the water returns to the ocean.

Transpiration from plants affects the climate in continential interiors and is an important factor in cloud production. The movement of such key elements as carbon, nitrogen, phosphorus, and oxygen through the Earth system are mediated by water in both liquid and gaseous forms.

Rapid hydrological events, such as droughts of fluxes of fresh water into saline estuaries, can cause substantial ecological changes on regional scales. Changes in sea level can have global impact on life as well as topography.

As the chart above shows, water, along with soil and carbon dioxide, are the links between the physical climate system and the Earth's biogeochemical cycles.

## Summary of the global role of water

**In the ocean**
- Heat storage
- Transport of heat and salt
- Form sea ice
- Solution chemistry
- Transport of chemical reactants
- Marine ecosystems
- Transport of nutrients
- Sedimentation

**In land ice and snow**
- Glacial modification of land forms
- Changes in sea level
- Radiation balance
- Storage

**In terrestrial ecosystems**
- Plant vascular system
- Diurnal temperature changes
- Environment for microorganisms
- Fresh water habitats
- Infiltration
- Decomposition
- Weathering
- Soil moisture
- Erosion
- Transport of eroded materials

**In the atmosphere**
- Latent heat of condensation
- Clouds and radiation
- Heat transport
- Precipitation
- Chemical reactant
- Washout

**Groundwater**
- Heat storage in lakes
- Hydrothermal circulation
- Solution chemistry
- Mineral fractionation
- Crustal viscosity

Source: Earth Systems Science Report, NASA Advisory Council - 1988

## Computer program in test phase

Work has been just been completed on a HyperCard program on the global climate. It is now being tested in local schools and, after this student testing, it will be made available to educators at a nominal cost

### HyperCard on the Mac

HyperCard is a system of information retrieval which works only on the Macintosh line of computers. The Knowledge Tree on Global Climate Change HyperCard Program consists of 3 floppy disketts. One contains the HyperCard operating system. The other two carry about 400 "cards" of information about the Physical Climate System and Global Climate Change.

HyperCard is unique in that it can store the cards and relate them to each other so that, at the touch of a button, any one of them can be displayed. Photographs, graphs, diagrams and sounds are also stored and displayed. Most intriguing, is the ability for the cards to be animated.

All of the techniques have been used in the Knowledge Tree Program. The development, which took place over a period of six months, has been funded by The Center for Science and Engineering Education, Lawrence Berkeley Laboratory, UC-Berkeley and was directed by CPI.

The next issue of the Greenhouse Gas-ette will carry details about the program.

## Carbonates in the Classroom

Calcium carbonate is in every classroom. It is the prime ingredient of chalk. (Some blackboard chalks contain $CaSO_4$ as well as carbonate.) Calcium carbonate is also secreted by many marine organisms to form their shells.

Surface sea water is supersaturated with it and it rains down to the ocean floor to from calcareous sediments. The process is an important part of the long term carbon cycle. This cycle takes carbon dioxide out of the atmosphere and sends the carbon under the Earth in a period which lasts about 500,000 years.

Carbonates make up limestone, coral, calcite, Tums, Rolaids, Alka-Seltzer, marble, pearls, chalk, oyster shells, and stalactites.

We would like to provide chemistry teachers with a lesson which would satisfy their syllabus requirements and, at the same time, give their students a laboratory experiment related to global warming.

### Chemistry Teacher Needed

Although we are able to suggest some work with the materials we need a chemistry teacher's insight on how to bring it together into a cohesive lesson. If you are that teacher, please send us an outline for a chemistry lab lesson. Or, if you are not - but if you know of one, please get that teacher to help.

Revelle Buffering Factor

$$\frac{(dpCO_2/pCO_2)\ TA, T, S}{(dTCO_2/TCO_2)\ TA, T, S} = R$$

1. A common test for carbonates is to treat with dilute HCl and test the gas evolved for carbon dioxide.

2. The carbon dioxide evolved above can be measured quantitatively by attaching the delivery tube to a $CaCl_2$-soda lime tube and weighing it.

3. The Solvay process for manufacturing sodium bicarbonate from common salt can be demonstrated by attaching a large balloon filled with carbon dioxide to a container of 100 ml conc. ammonia solution saturated with salt.

Alyea's *Tested Demonstrations in Chemistry* suggests that the air be flushed out of the container with carbon dioxide before the balloon is attached with a one-hole stopper and short tube. Shake the container to dissolve the carbon dioxide and look for the sodium bicarbonate precipitate to form in 20-30 minutes.

### Carbon Dioxide in Seawater

A chemistry lesson could be constructed on the above topic. It could take up the subject of equilibrium with atmospheric carbon dioxide or the alkalinity of sea water could be the focus.

Alternately, the buffering action of seawater could be the subject. When carbon dioxide is added to seawater the principle effect is to remove the carbonate ion:

$$CO_2 + CO_3^{--} + H_2O \rightarrow 2HCO_3^-$$

There is considerable resistance to this reaction. The buffer factor (Revelle factor) is at the left.

TA - is the total alkalinity
T - is the temperature
S - is the salinity
$TCO_2$ - is the total concentration of carbon dioxide in all its forms
$pCO_2$ - is its partial pressure

# Earth Day 1990 - The Pledge

**Because ... our planet today faces serious environmental problems such as destruction of the world's forests, pollution of our land and water, destruction of the ozone protection layer in the sky, extinction of many plants and animals, and the strong possibility that we are causing major changes in the climate**

**Because ... the planet's future and my future depends on the actions of every nation and every person**

## I pledge to do my share in saving the planet by choosing to do one or more of the following:

### (1) I pledge to use less energy

I will turn off lights, radios, televisions and other electrical appliances when I am not using them

I will walk, ride my bike, or use public transportation instead of driving or having someone drive me

I will wear a sweater instead of turning up the heat inside my house

### (2) I pledge to use less water

I will turn off water when brushing my teeth or shaving

I will take shorter showers

I will ask and/or help my family put in water saving shower heads, faucet aerators and toilet bowl water savers

### (3) I pledge to do the 3 R's: Reduce, Re-Use, and Recycle

**Reduce:** I will only buy things that I really need; I will put things that I buy in my backpack instead of having the store put them in a bag

**Recycle:** I will start or continue recycling glass, paper and aluminum cans in my home and school

**Re-Use:** I will use both sides of paper; I will use the same lunch bag many times.

### (4) I pledge to work with others to help save the Earth

I will join other students in a club to help save planet Earth

I will get at least ten other people to sign the Earth Day Pledge

I will learn about the environment and teach others

---

I am signing this pledge because I care about the Earth and all its life

(signature) _____

School _____ Grade _____

This newsletter is distributed free of charge to educators interested in developing lessons related to global climate change. In the interest of conservation, please pass it on to someone who you think might be interested in it.

**In this issue** **Page**


- Tragedy of the Greenhouse Effect ..... 1
- Earth Day - 1990..... 3
- Soil microbes changed the climate..... 4
- Energy trapping, dynamic equilibrium experiment and demo ..... 5
- Global role of water ..... 9
- Carbonates and sea water..... 10
- Earth Day Pledge sheet ..... 11



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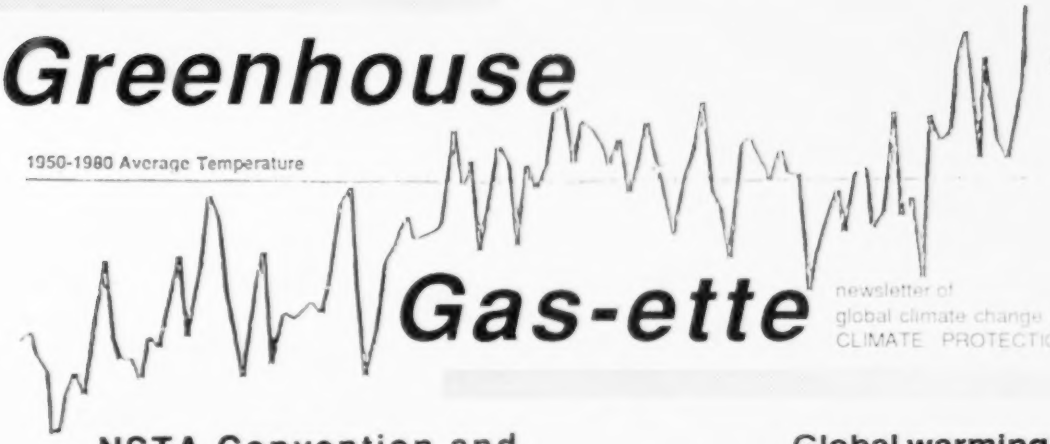
*"The amount and rate of climate change depend on how people behave."*
Dr. Stephen Schneider

# Greenhouse Gas-ette

Spring 1990

newsletter of global climate change education
CLIMATE PROTECTION INSTITUTE


## NSTA Convention and Global Warming

Science teachers by the thousands, approximately 17,000 of them, flooded into Atlanta, GA for the annual National Science Teachers Association Convention, April 5-8.

Featured speakers Carl Sagan and Jeremy Rifkin, in separate presentations, focused the attention of the teachers on the threat of global warming.

In his speech Carl Sagan made the connection between planetary research and increasing knowledge to understand and protect our own planet. (In this connection the *Greenhouse Gas-ette* recommends an article in the Feb., 1988 issue of Scientific American, How Climate Evolved on the Terrestrial Planets.)

### Carbon dioxide- the key to a planet's climate

Dr. Sagan was joined in his presentation by Roald Sagdeev, Deputy to the People Congress, USSR and head of the Theory Division of the Russian Space Research Institute. While pointing out the results of too much $CO_2$ on Venus and too little on Mars they emphasized that the Earth was not likely to follow those extreme examples. But, they warned that if human activity continues to add $CO_2$ to the Earth's atmosphere severe climate disruptions will be experienced by future generations.

The title of Jeremy Rifkin's speech was "The Greenhouse Crisis in Global and Environmental Security." Rifkin, president of the Greenhouse Crisis Foundation, made the point that global warming is a threat to the security of the world.

Disruptions in agriculture brought about by changed weather patterns could mean starvation for millions in different parts of the world. The effort to protect coastal cities from higher sea levels could absorb the wealth of nations and leave their economies stagnant.

Both presentations pointed to the important role of educators in providing information and understanding to next generation which will have to cope with the problem.

### Workshops on global warming

There were many workshops and reports related to global environmental concerns. Of particular interest was the work of Prof. Victor Mayer of Ohio State University in developing an Earth Systems Education program in which science education is focused on the study of the Earth.

This issue of the *Greenhouse Gas-ette* is devoted to the reproduction of the activities presented in one of the NSTA workshops.

## Global warming and the high school classroom

The above was the title of the workshop presented by Cary Sneider of the Lawrence Hall of Science, U.of C.-Berkeley, and Richard Golden of CPI. Although the room could only seat 80 teachers, 120 of them crowded in and many more stood outside in the hall.

### Activities for the high school classroom

Some of the activities presented during the workshop have already appeared in the pages of this newsletter. The pages that follow contain some of those that have not previously been printed.

Most of the information is written in the form of worksheets for your students. Please feel free to reproduce them for your own and your colleague's classroom use. Permission to use the material in any other way must be obtained from CPI in writing.

If you have any suggestions, corrections and/or additions to make to these activities, please send them in. Your input can make them better.

Make the *Gas-ette* a clearinghouse for activities on global warming.

Send in your ideas and suggestions to share with over 4,000 colleagues.

# Confusion about global warming

It is to be expected that the prospect of social disruption caused by a change in the world's climate would arouse strong tendencies toward denial or hopeful "wait and see if its real" attitudes.

President Bush who told us, before election, that those who are concerned about the greenhouse effect should remember "the White House effect" has not taken any action on the problem.

A recent paper (March 30 SCIENCE) indicated that satellite measurements of the Earth's lower atmosphere showed no warming trend over the past 10 years. This report was extensively reported in the media and quickly picked up as casting doubt on the predictions of global warming.

### Is the threat of global warming just so much hot air?

The authors of the paper took pains to point out the relatively short time span of their study. They said that their data could not be used to disprove that atmospheric warming was not underway.

They also pointed out that they were measuring a thick region of the lower atmosphere which might be different from trends at the surface.

An international team of scientists assembled by the United Nations says in it's draft report that it is a "virtual certainty" that the Earth's surface will warm substantially in the next century. (New York Times, Apr. 16, 1990)

This team's report was prepared for a meeting of the representatives of 17 nations and the European Community which is to be held in Washington. The meeting, called by the White House, is intended to integrate scientific and economic research on the problem of climate change.

### Ice core records

The theory of greenhouse warming is based on a substantial body of evidence. One portion is the result of the examination of ancient air in bubbles taken from the ice cores obtained at Vostok in Antarctica.

The record of carbon dioxide concentrations over the last 160,000 years has been obtained. When plotted with the record of the general temperature changes of the Earth over the same time period the above graph results. The correlation between global temperatures and concentration of carbon dioxide is remarkable.

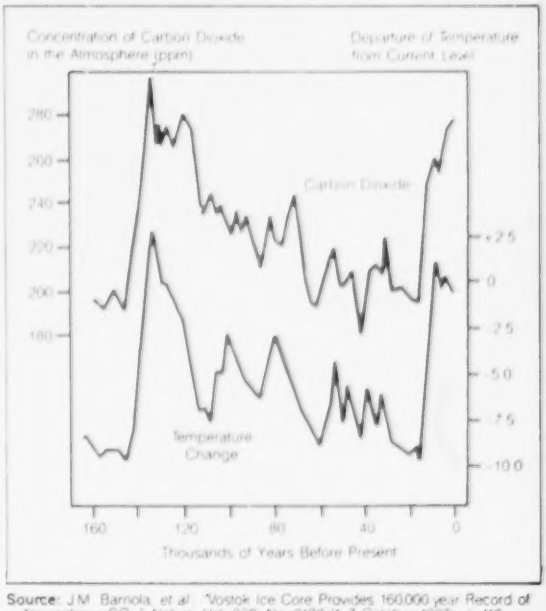
The likelihood of a process that will counteract the climatic effect of our present carbon dioxide buildup is remote. Although clouds may increase and shade the surface, the historical record is clear; more carbon dioxide - more global warming.

### Buying insurance

Society has embraced the concept of payment of insurance premiums to mitigate the consequences of expected catastrophes. To wait until the catastrophe of global warming is upon us before taking action is less than prudent. If we begin to reduce our impact on the global environment now, if we reduce our demand for electricity produced by the burning of fossil fuels, if we demand more efficient automobiles, wherein lies the harm?

Nature is telling us in many different ways, other than global warming, that the way we live is not conducive to the long term health of our planet. Insurance payments of small changes now would seem to be indicated to avoid large disasters in the future.

**Long-Term Variations of Global Temperature and Atmospheric Carbon Dioxide**




Source: J.M. Barnola, et al. "Vostok Ice Core Provides 160,000 year Record of Atmospheric $CO_2$." Nature, Vol. 329, No. 6138 (1-7 October 1987), p. 410.

World Resources 1988-89

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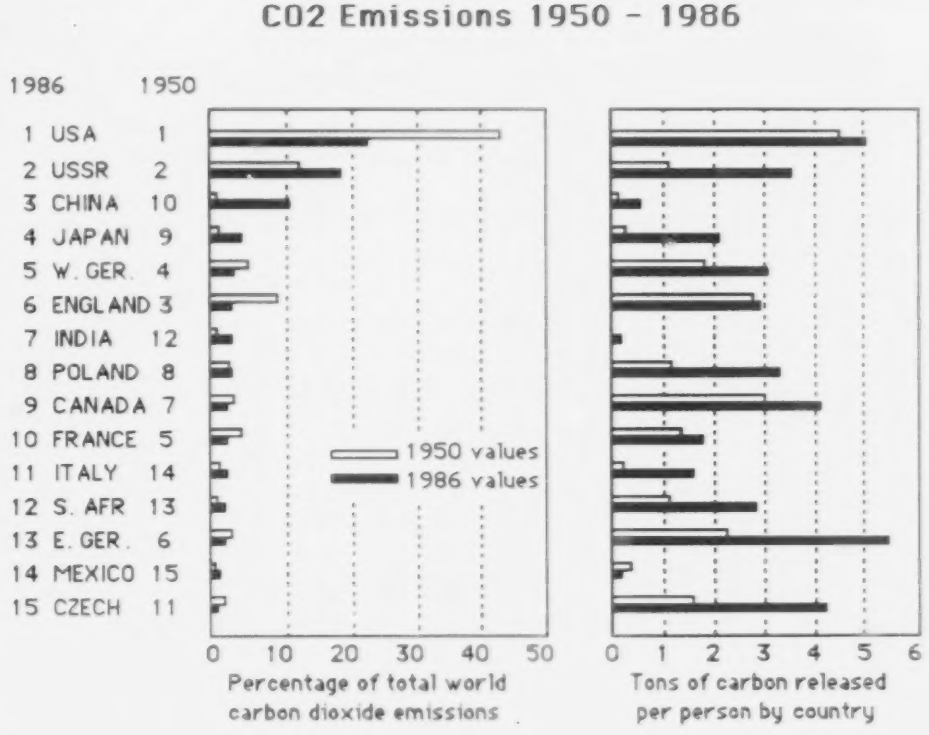
**Connections:**

- Graph interpretation
- Personal $CO_2$ production
- Population changes
- World wide relationships
- Global climate change

# Carbon Dioxide Emissions

Graph source: CDIAC Communications - Winter, 1989
Carbon Dioxide Information Analysis Center
Oak Ridge National Laboratory




**Using the graphs answer the following questions:**

1. Of the total world's $CO_2$ emissions what % was emitted by the U.S. in 1950? What % was emitted in 1986?
   In 1950 U.S. industry emitted 679 million metric tons of $CO_2$ into the air. In 1986 it had increased to over 1190 metric tons. Why do you think the % of the total world emission of $CO_2$ from the U.S. changed the way it did?

2. What country went from being the 9th largest emitter of $CO_2$ in 1950 to the 4th largest emitter in 1986?
   What reasons can you think of to account for the change?

3. How many countries account for approximately 50% of the world wide emission of $CO_2$ in 1986?

4. How does the national distribution of $CO_2$ emissions in 1950 compare to those in 1986?

5. How many tons of carbon was each person in the U.S. responsible for in 1950? How much in 1986? How can you explain the change given the fact that there were even more people in the U.S. in 1986 than there were in 1950?

6. What % of the world's $CO_2$ emissions came from East Germany in 1986? How many tons of $CO_2$ were emitted for each person in East Germany in 1950? How many in 1986? What two reasons might there be for the change in amount released for each person?

7. For Mexico did the % of total world emission of $CO_2$ rise or fall from 1950 to 1986? What happened to the amount of carbon released by each person in Mexico in those time periods? How could you account for the change?

8. Compare the release of carbon per person for all countries in 1950 with that released in 1986. What can you observe is happening world-wide with regard to the release of $CO_2$ into the atmosphere?

9. Given the fact that increased $CO_2$ emissions will result in a general warming of the Earth, what course of action do you believe should be followed by an international organization concerned with the problem?

**Connections:**

- Global climate changes
- Rate of flow
- Sea level rise
- Change in Earth's albedo
- Feedback effect

# Glaciers and Global Warming

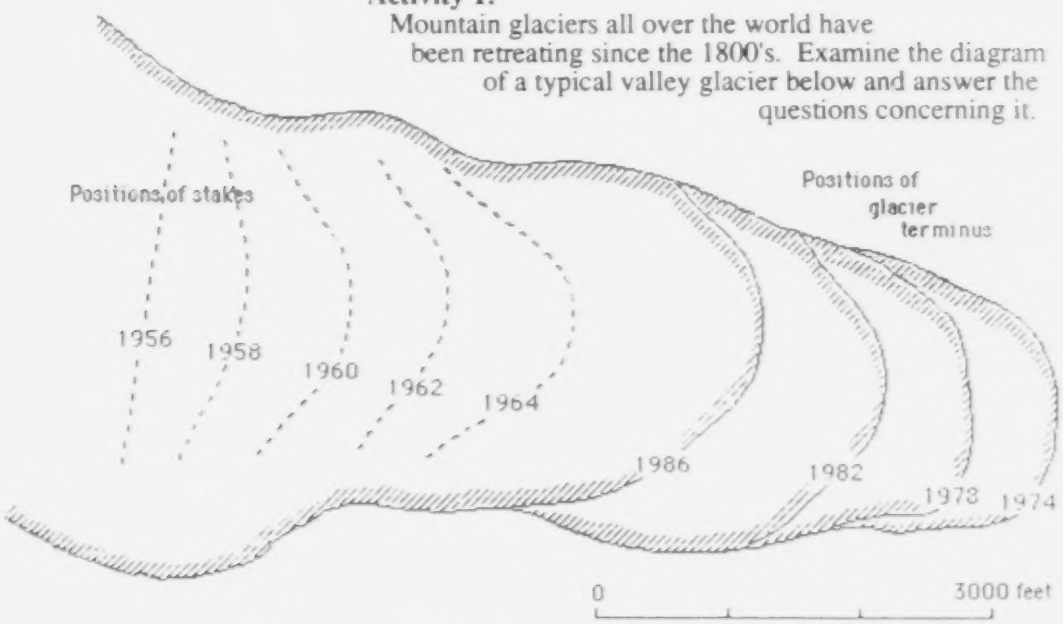
**Background:**

When climate conditions are such that more snow falls during the winter in mountainous areas than melts during the summers, the accumulation results in a slow moving mass of ice. The tremendous pressure of overlaying snow mass that builds up over the years compresses the recrystallized snow and causes it to flow downhill dragging rocks and soil and sculpting the land. These masses are called glaciers.

If the climate is cold, the mass of the glacier increases and the front edge of ice advances. If, however, the climate warms, more glacial ice melts during the summer than is replaced by the downhill creep and the leading edge of the glacier retreats relative to the surrounding landscape.

**Activity 1:**

Mountain glaciers all over the world have been retreating since the 1800's. Examine the diagram of a typical valley glacier below and answer the questions concerning it.




The dashes on the line "1956" indicate the positions of metal stakes driven into the ice of the glacier in that year. The other dashed lines, 1958 through 1964, represent the positions of those same stakes at 2 year intervals.

1. Using the scale provided, determine the average annual rate of flow near the center and along either edge.

2. Write a hypothesis that might explain the difference in these flow rates.

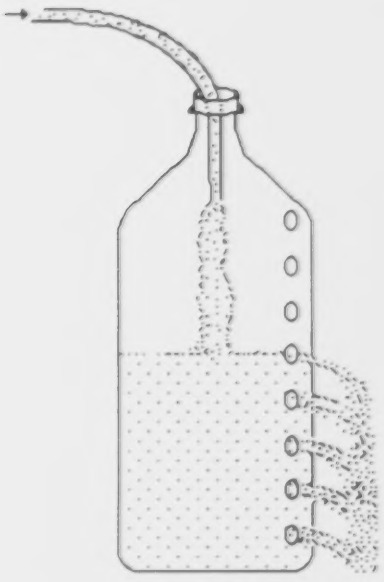
3. Determine the average annual rate of retreat of the terminus.

**Activity 2:**

**Rate of flow demonstration:**

Obtain a 2 liter clear plastic bottle and with a phillips screw driver melt a series of vertical holes in its side.

Place it in a sink or catch basin and vary the flow of water into it. What will happen if the rate of inflow is greater than the outflow? What if the inflow is reduced, or if the holes are made larger?



If this model represented a glacier:

1. What does the inflow of water represent?
2. What does the change in liquid level in the container tell us about a glacier?
3. What would enlarging the holes illustrate about a glacier?
4. How might the action represented by enlarging the holes be accomplished in nature?

**Compression calculation**

A cube of ice 1 cm on each side weighs 0.9 gram. It is estimated that approximately 6 kg per square cm of pressure is required to make ice begin to flow. How tall must a mass of ice cubes be to cause the bottommost layer to flow. How many feet is that?

**The global warming connection**

The greenhouse effect is the increased warming of the Earth due to the retention, in the atmosphere, of heat which is radiated from the sun-warmed surface. If the present rates of emission of the greenhouse gases which cause the greenhouse effect continues, the Earth will be faced with a global warming of the climate unprecedented in human history.

1. If the climate warms and glaciers continue to melt, what can be expected to happen to the sea level?

2. What other property of water might be responsible for sea level change as the climate warms?

3. What would the melting of floating sea ice contribute to sea level change?

4. The reflectivity of the Earth's surface is called its "albedo." If the surface area of glaciers and snow fields in the polar regions decreases, will the Earth reflect or absorb more of the Sun's energy?

5. If the albedo of the Earth decreases, will that reduce the warming of the global climate or increase it?

6. As far as warming of the Earth's climate is concerned, is the melting of glaciers a negative or a positive feedback effect? Why?

**Information:**
Feedback effects are called negative when they reduce the change. They are called positive when they add to it and make it progressively worse.

**Connections:**

- Greenhouse gas concentrations
- Earth's thermal emission curve
- Infrared spectrum
- Math calculations
- Rate of change calculations

# Greenhouse Gases - Facts and Figuring

Sources: Wuebbles, D., and Edmonds, J., A Primer on Greenhouse Gases DOE/NBB-0083 March, 1988
New York Times, Feb. 7, 1989

**Background:**

Although carbon dioxide is the most plentiful and best known, there are other gases that also contribute to the build up of heat in the atmosphere - the greenhouse effect. Although the quantity of each of these gases is less than that of carbon dioxide each of them have greater heat-trapping power, molecule for molecule, than carbon dioxide. The total heat trapping of the other greenhouse gases now is about equal to that of carbon dioxide alone.

Climate modelers often base their calculations of the timetable of future climate changes on what would happen if the atmospheric concentration of carbon dioxide was doubled. But it is the rates of emission of all the greenhouse gases and their annual increases plus their individual heat trapping power, that are the actual factors that will determine the timetable of climate change and the calcuations get complex.

**Carbon dioxide**
Pre-industrial level - 275 ppm
1986 level - 346 parts/million

If feedback effects, like melting snow cover and warming oceans, are included, doubling of $CO_2$ conc. could increase global average temp. by 1.5 - 4-5°C.

On its own, doubling $CO_2$ could increase surface temp. by 1.3°C

Principal range of infrared absorption: 12.3-18 microns
Current annual increase: 0.4%

**Methane**
25 times $CO_2$ heat trapping
Pre-industrial level - 0.75 ppm
1986 level - 1.7 parts/million

Doubling methane could increase surface temp. by 0.3°C

Range of infrared absorption: 6.1-10.5 microns
Current annual increase: 1%

**Nitrous oxide**
250 times $CO_2$ heat trapping
Pre-industrial level -280 ppb
1986 level - 305 parts/billion

Doubling nitrous oxide could increase surface temp. by 0.4°C

Principal range of infrared absorbtion: 7.4-9.3 microns
Current annual increase: 0.2%

**Doubling formula:**

Given the percent of growth, the year when doubling of the growth item will take place is given roughly by the following formula:

$$\text{Approx.time (years)} = \frac{72}{\%\ \text{growth}}$$

Example: For population growth rate 2%
Doubling $\doteq$ 72 / 2 % = 36 years

**Question 1.** Based upon the values of the Current Annual Increases of the different greenhouse gases which are given (also see the other side of this page), which gases are increasing their concentrations most rapidly?

**Question 2.** If there where 346 $CO_2$ molecules mixed in a million air molecules in 1986, what percent of the total volume of air is $CO_2$ ?

**Question 3.** By what percent has the amount of $CO_2$ in the atmosphere increased since the advent of industrialization?

**Question 4.** Make a list of the greenhouse gases in order of their 1986 concentration in the atmosphere, highest to lowest. Some of them are present in only very small trace amounts compared to the most voluminous absorber of infrared radiation. From the data given for the various greenhouse gases, why are scientists warning that these trace gases are a danger to the global climate?

**Question 5.** Using the doubling formula and the current annual rate of increase when would you expect the amount of $CO_2$ in the atmosphere to double? Some scientists use the year 2060 as the approximate date of $CO_2$ doubling. Why do you think that figure is so different from the one you calculated?

**Ozone - low level**
300* times $CO_2$ heat trapping
Level varies between 0.02 - 0.1 parts/million but can be 2 or 3 times higher in urban polluted areas. High level ozone concentration is decreasing because of the action of CFCs. *(High level ozone decreases surface temp. by absorbing solar radiation.)

Doubling low level ozone could increase surface temp. by 0.6°C

Ranges of infrared absorption:
8.3-10.5 and 12.5-16.6 microns
Current annual increase: 0.25%

**Water vapor**
Level varies-dependent on temp.

Range of infrared absorption:
Over most of the IR spectrum but in the "window of terrestrial radiation" where most of the Earth's IR energy is emitted, water vapor is relatively inefficient.

**Information:** Wave lengths of radiation are measured in parts of a meter. A **micron** is 1 millionth of a meter.
1 micron = 1 x $10^{-6}$ meter = 1/1,000,000 meter

Most of the light from the sun is in the range of from 0.4 to 0.8 microns.

**Fluorocarbon 11 (CFC-11)**
17,500 times $CO_2$ heat trapping
Pre-industrial level -none
1986 level - 230 parts/trillion

Doubling CFC-11 could increase surface temp. by 0.3°C

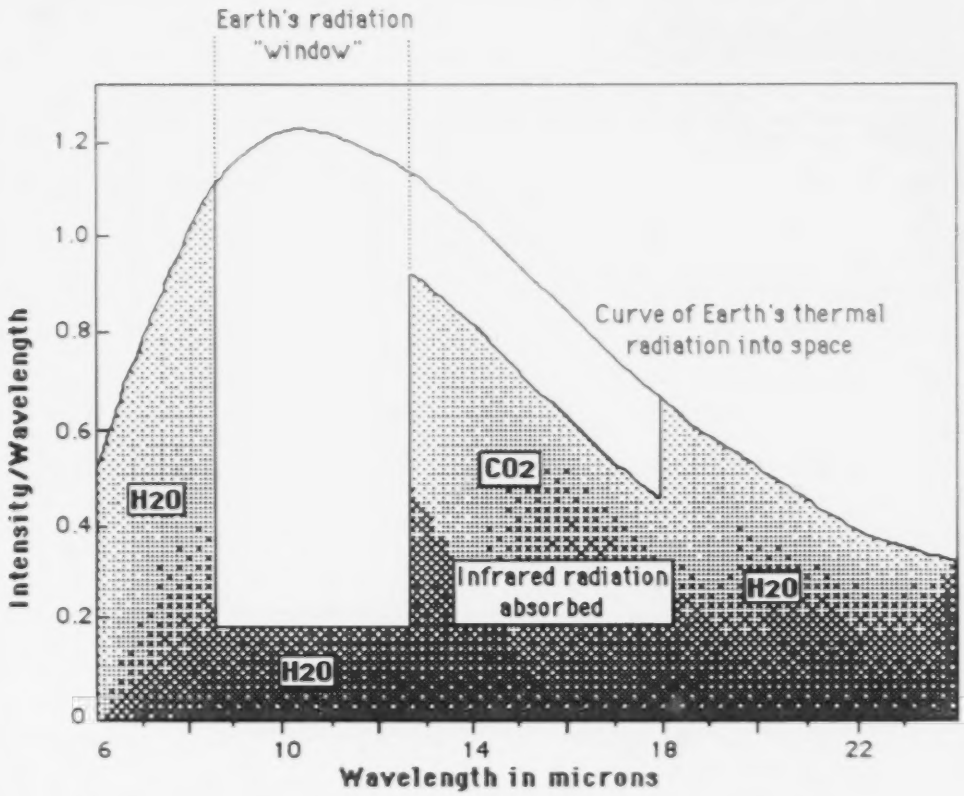
Range of infrared absorption:
8.3-12.5 microns
Current annual increase: 5%

**Fluorocarbon 12 (CFC-12)**
20,000 times $CO_2$ heat trapping
Pre-industrial level - none
1986 level - 400 parts/trillion

Doubling CFC-12 could increase surface temp. by 0.3°C

Range of infrared absorption:
8.0-11.8 microns
Current annual increase 5%

**Information:** The full range of terrestrial infrared (IR) radiation extends from 5 to about 100 microns. However, because water vapor absorbs IR radiation poorly in the range of 8.5 to 12.5 microns, and because Earth's radiation is most intense in this range, it is called the "window for terrestrial radiation.




**Question 6.** On the graph to the left the gray areas represent IR radiation which is absorbed and produces the greenhouse effect.
Draw horizontal lines in the area between 1.0 and the top which correspond to the absorption ranges of all of the greenhouse gases.
Why can very small amounts of some gases exert a warming effect as great as that caused by the much more abundant $CO_2$?

**Question 7.** When scientists say that human beings are "dirtying up the Earth's radiation window," what do they mean?

**Question 8.** What do you suggest be done about it?

Adapted from: MacDonald, G., Climate Change and Acid Rain, MITRE Corp., 1985

**Connections:**

- Migration
- Animal territoriality
- Temperature dependent range
- Interdependence
- Rate of adaptation
- Biodiversity

# Kirtland's Warbler - a casualty of the greenhouse effect?

This lesson is the work of: Dr. Dorothy B. Rosenthal
Science Education Program
Cal. State Univ., Long Beach

**Activity:** Read the case study that below and then answer the questions that follow.

**Information:**

Kirtland's warbler is named for the Michigan farmer who first discovered it in 1851.

Like all warblers it is a tiny bird, an adult male weighs less that half an ounce.

It is rare and has beautiful gray-blue and pale lemon plumage.

The warbler's short melodic song can be interpretated as "Please, let me be-- let me be, will you please."

It has become the "pet" bird of Michigan.

**The case of Kirkland's Warbler**

The bird winters in the Bahama Islands and migrates north to central Michigan each spring. There, males establish territories several acres in area. Their songs serve to defend their territories from other males and to attract mates.

The pairs build nests in stands of young jack pines, which grow on the unusual coarse sandy soil found in parts of Michigan. Kirtland's warbler is extremely particular about where it lives. Its entire life cycle is dependent upon the presence of 5-6 year old jack pines and the coarse sandy soil. These conditions are found in only a small area in Michigan, now about 1/2 million acres. Anything that reduces the number of young jack pines is bound to have an effect on the warbler.

The jack pines depend on periodic fires for the germination of their seeds. In the ages past lightning, Indians and logging caused many fires. As farming spread through the region the area of the jack pine forest decreased. In spite of efforts of wildlife agencies to save the warbler from extinction the numbers of Kirtland's warbles have continued to decline.

**The greenhouse connection**

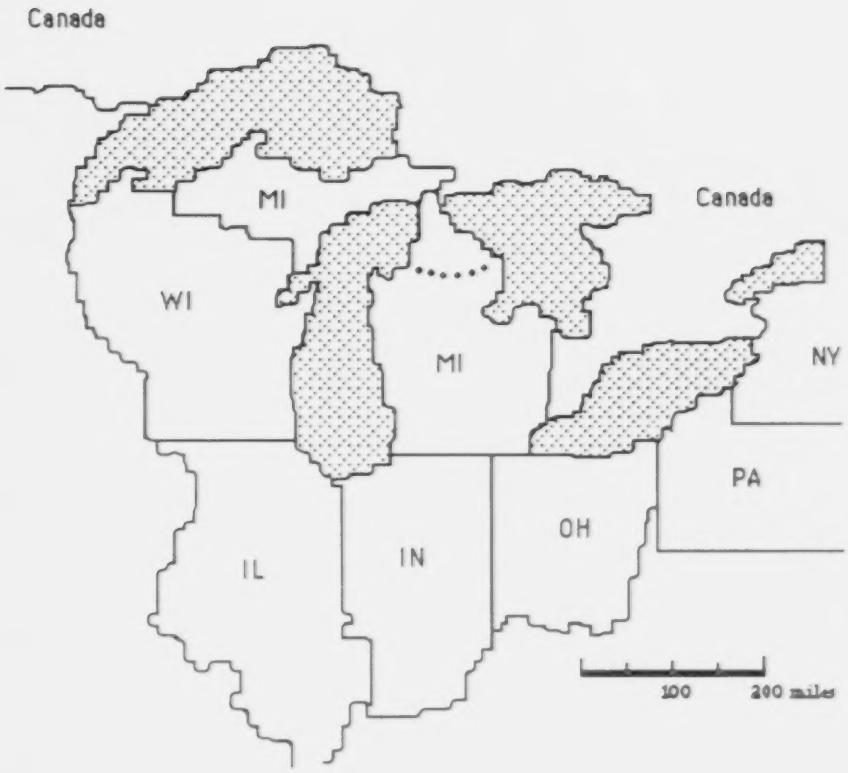
Jack pines are extremely sensitive to temperature. Those in the area where the Kirtland's warbler lives are at the southern edge of their range. Most of the jack pines are found in the cooler climates to the north where soil conditions are unsuitable for the warblers. Any increase in temperature, as from an increased greenhouse effect, would push the range of jack pines northward. This would further reduce the habitat of the warbler.

Researchers at the University of California in Santa Barbara* have suggested that decline in the numbers of Kirtland's warblers may be used as a sensitive warning of climate change in the same way that canaries, carried underground by miners, used to warn them of "bad air" by their death.

* Botkin, D. B., Woodly, D. A., and Nisbet, R. A., 1989. Kirtland's Warbler Habitats: A possible early indicator of climate warming. Unpublished manuscript

**Questions:**

1. A 1° C change in the annual average temperature will cause growing regions of plants to migrate 100 to 150 kilometers to the north. Climate scientists expect that at the rate we are going the increased green house effect will increase the global temperature approximately 4° C by the year 2030. How many kilometers north will the jack pine forest have moved? How many miles is that?




2. The outline map shows the present southern boundary of the jack pines. Show where the southern boundary would be in 2030, given a 4° C increase in global average temperature.

3. The area inhabited by Kirtland's warbler has a radius of about 100 kilometers. Would the amount of movement of the jack pine forest that you calculated in #2 affect the Kirtland's warbler?

4. Forests are known to have adapted to temperature changes of 1° C over 1000 years. How do you think the predicted change of global average temperature from 1.5 to 4.5° C in less than 100 years will affect the jack pines?

5. If the warmer climate causes more frequent forest fires, how might that affect your answer to #4?

6. A forest, such as the jack pines, is not just a home for one type of bird. Many types of organisms, plants and animals, live there. Over many millions of years they have grown adapted to the climate and to each other. They form a closely-knit community of organisms that depend on each other. Even if the jack pines are able to migrate northward, other members of the forest community may not be. The result would be the extinction of many organisms. Organisms that are already endangered, such as Kirtland's warbler, would be especially affected. Why do you think the preservation of a large number of species is important for humans?

**Extension:**

Although many species of plants and animals might be endangered by global warming, those already endangered now would probably be affected first.

Select a plant of animal already endangered and research its life history. On the basis of what you find out, predict how it may be affected by global warming.

**Connections:**
- Greenhouse gases
- Conversion factors
- Math calculations
- Energy conservation

# Family Production of Carbon Dioxide

**Background:**

Although other trace gases in the atmosphere like methane, nitrous oxides, chlorofluorocarbons, and ozone collectively contribute an equal amount to the greenhouse warming of the Earth as does carbon dioxide, it is the carbon dioxide that is the largest single source of the warming. All fossil fuels when burned produce carbon dioxide although in different amounts. The industrial world's demand for energy has been chiefly responsible for the 25% increase in atmospheric carbon dioxide over the past 100 years.

**Conversion factors - direct production**

Burning 1 gallon of gasoline = 20 pounds of $CO_2$

Using 1 kilowatt-hour of electricity *
- produced by burning coal = 2.6 pounds of $CO_2$
- produced by burning oil = 2.0 pounds of $CO_2$
- produced by burning natural gas = 1.6 pounds of $CO_2$
- produced by hydropower, windpower, co-generation, geothermal or nuclear energy = 0 lbs $CO_2$

Burning 100 cubic feet of natural gas produces 100,000 BTU (1 Therm) = 12 pounds of $CO_2$

**Indirect production of $CO_2$ from purchase of goods and services**

Take the amount of $CO_2$ from direct production x 2

Sources: Udall, James R., *Domestic Calculations* in Sierra, July/Aug., 1989
* Lawrence Berkeley Lab., U.C.-Berkeley, CA

Each of us is part of that industrial society and we must each share the responsibility for the global climate change that stems from the additional carbon dioxide in the atmosphere.

**Activity 1:** Find out how many miles vehicles in your family are driven in the course of a year. If the miles per gallon is unknown assume your car(s) get 28 mpg.

Using the conversion factor, how many pounds of carbon dioxide are released by your family's driving.

**Activity 2:** Obtain the monthly bills for the electricity and gas used in your home or apartment for the year. If the whole year's bills are not available, try to get a March or October bill and multiply by 12. (Using a summer or winter bill alone and multiplying would give an amount either too low or too high.) Calculate the number of heating therms and kilowatt-hours your family used in a year.

Find out, by calling your utility company's customer representative, what percentage of its electricity is produced by burning coal, oil or natural gas, and what percentage is produced from other sources. Calculate how many pounds of carbon dioxide your family produced by your direct use of electricity and natural gas in the course of a year.

**Public Utility Company Example**

The Pacific Gas and Electricity Company which serves much of California uses the following energy sources in producing the electricity it sells.

| | |
|---|---|
| Coal | 0% |
| Oil | 4% |
| Natural gas | 35% |
| Nuclear energy | 20% |
| Hydropower | 13% |
| Geothermal | 10% |
| Co-generation, windpower and purchases | 18% |

**Activity 3:** Energy experts say that the carbon dioxide released per family during the production of the things we buy and the services we use, is about equal to the amount of carbon dioxide produced by our direct use of energy. What, then, is the total amount of carbon dioxide produced by your family during the year?

**Activity 4:** If your family's car(s) were more efficient and got 5 more miles per gallon, how many pounds of carbon dioxide would be prevented from going into the air each year? There are about 180,000,000 cars, buses and trucks on the roads of the United States. How many pounds of carbon dioxide pollution would be saved each year if they all improved their efficiency and got 5 more miles per gallon?

**Activity 5:** Make a list of other actions that your family could take to reduce carbon dioxide emissions. Estimate how much less carbon dioxide would be produced if all the 92,000,000 households in the U.S. followed your suggestions.

# Answer Sheet

## Carbon Dioxide Emissions

1. 43%; 23%; Although U.S. increased its emissions other countries did so also and to a greater extent.
2. Japan, increased industrialization
3. 3, U.S., USSR, China
4. 1956 - dominated by U.S. 1986 - more countries involved
5. 4.5; 5.1; rate of emissions of carbon dioxide increased
6. 3%; 2,3 tons; 5.5 tons; move industrialization, fewer people
7. rise; fell; more people, no increase in industrialization
8. the amount is increasing
9. (student answer)

## Glaciers and Global Warming

Activity 1

1. center - 775 feet/year; edge - 525 or 575 feet/year
2. edge friction
3. approximately 770 feet/year

Activity 2

1. snowfall
2. if snowfall increases the volume of glaciers increases
3. increased melt and runoff
4. climate warming

Compression calculation - 6666 cm or 236 feet

Global Warming Connection

1. sea level rise
2. expansion of water
3. nothing
4. absorb
5. increase it
6. positive feedback, adds to the effect

## Greenhouse Gases - Facts and Figuring

1. CFC11 and CFC12 - 5%
2. 0.035 %
3. 26%
4. CO2, methane, nitrous oxide, ozone, CFC11, CFC12; great heat trapping power and in the range of Earth's radiation "window"
5. 180 years; current annual increase of 0.4% is not constant, it is accelerating. other feedback processes change the present absorption rate
6. (same as #4b)
7. trace greenhouse gases produced by human activities are blocking infrared radiation in the previously open range
8. (Student answer)

## Kirtland's Warbler

1. 400 to 600 kilometers; 240 to 360 miles
2. (into Canada)
3. yes, eliminate its habitat
4. dieback of jack pines in southern range
5. further reduction of jack pine forest
6. (Student answer)

NEW!

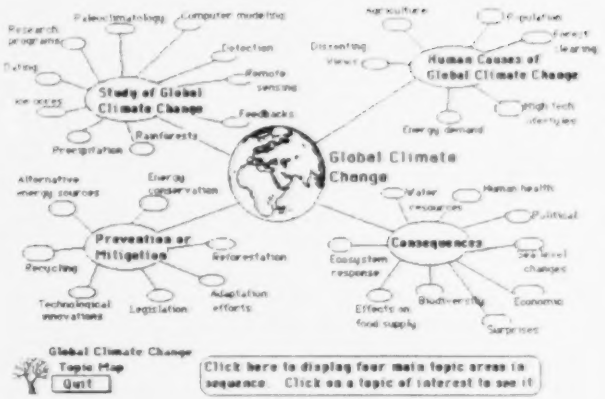
# GLOBAL WARMING PROGRAM
## for the Macintosh computer

DISK 1 - THE CLIMATE SYSTEM

DISK 2 - GLOBAL CLIMATE CHANGE

DISK 3 - SYSTEM AND HYPERCARD©

**$15 for the 3 disks**


Study of Global Climate Change
Human Causes of Global Climate Change
Global Climate Change
Prevention or Mitigation
Consequences
Click here to display four main topic areas in sequence. Click on a topic of interest to see it!

The Climate Protection Institute, in conjunction with the Center for Science and Engineering Education at Lawrence Berkeley Lab., UC-Berkeley, has produced a HyperCard© information retrieval program on Global Climate Change.

The 3 diskette system requires a Macintosh computer with a minimum of two disk drives. One disk holds the HyperCard© operating program. The other two are data disks. The topic headings of the data disks are reproduced above

Any of the topic headings are immediately callable. Related information is retrieved at the touch of the mouse button. The user can follow the branching knowledge paths in any direction.

There are about 400 "cards" of information with text, graphics, animation and sounds. As new information is developed updated versions of the program will be made available through a diskette exchange program.

For the three diskette set of the KNOWLEDGE TREE ON GLOBAL CLIMATE CHANGE, please send $15 to

**Climate Protection Institute**
**5833 Balmoral Drive**
**Oakland, CA 94619**


CLIMATE PROTECTION INSTITUTE
5833 Balmoral Drive, Oakland, CA 94619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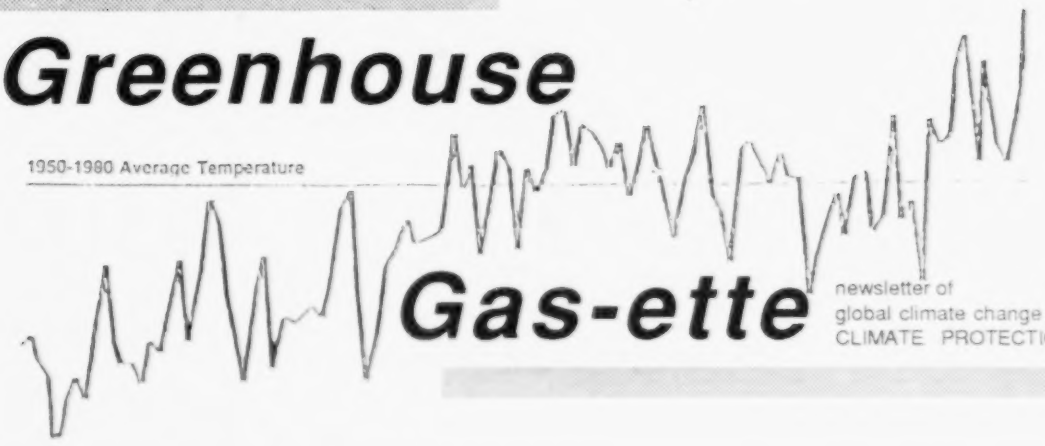
*"The amount and rate of climate change depend on how people behave."*
Dr. Stephen Schneider

# Greenhouse Gas-ette

Fall 1990

newsletter of
global climate change education
CLIMATE PROTECTION INSTITUTE


## Teenager speeds international ozone agreement

(UNEP North America News)

Pass this story on to your Social Studies colleague

Agreement was reached on June 29th at the London Ozone Layer Conference to halt production of ozone destroying chemicals. It was signed by the European Community and 53 of the 57 countries that ratified the 1987 Montreal ozone treaty, and it was approved by 40 other countries.

The conferees agreed to phase out ozone destroying CFCs by the year 2000 and to speed the development of safer substitutes. For the first time, a limit was set on the use of two other ozone depleting gases, methyl chloroform and carbon tetrachloride.

### Youth delegate speaks up

None of this may have happened were it not for the presence of a youth delegation from Australia. When the experts began their negotiations they had before them a text teeming with amendments and adjustments, including 190 square brackets like this [ ] around words and phrases - all representing disagreements. They had made little headway in removing them when Susannah Begg, a teenage member of the Australian youth observers, told the conferees and their official delegations.

"We have been watching you. It has been at times fascinating, at times confusing, at times horrifying.... We have had to keep reminding each other that what is actually being debated here is the future of the ozone layer. This debate has been largely guided by short-sighted commercial gains and national self-interest.... Your pursuit of diplomatic compromises is compromising our future.... Remember that we will inherit the consequences of your decisions. We will not sign the Montreal Protocol - you will. You will not bear the brunt of ozone depletion - we will. We demand that you think in the long term.... Our fate is in your square brackets."

Two days later all 190 sets of brackets disappeared to make way for a stronger ozone treaty.

In a reversal of its previous position, the US has agreed to contribute to an international fund to aid the lesser developed countries to phase out production of CFCs.

---

**Note:** While ozone layer depletion does not increase global warming, the chemical that attacks ozone, CFC, is also a greenhouse gas and is part of both problems.

## Scientific American publishes articles on climate change

America's premier scientific publication had articles of interest in both the July and August, 1990 issues. July's lead article, "The Great Climate Debate" outlines the development of the awareness of the possibility of global warming. It describes the objections to, and reasons for, action at this time

Some of the debate on the issue of climate change centers on whether the globe has actually warmed in the past century. In the August issue two well respected climatologists report on their exhaustive analysis of land and marine records.

The results indicate that the Earth has indeed warmed by 0.5°C in the last 100 years. This warming is at the lower end of computer model predictions. The authors suggest that the greenhouse effect may be smaller than predicted by current models or that it is stronger, and is being partially offset by natural variations.

### No excuse for inaction

They conclude by noting that the uncertainties should not be used as an excuse for delaying climate protection policies. Only if the research showed no warming would inaction be justified.

# UN scientists say climate change will have devastating effects on millions

UNEP North America News

Unless emissions of carbon dioxide and other greenhouse gases are quickly cut by more than 60% people, animals and plants will be severely affected over the next century. This was the conclusion of three draft reports distributed to governments by the Intergovernmental Panel on Climate Change (IPCC).

This will mean that policy makers will be faced with difficult decisions when they meet this November to start work on a strategy and an international convention to slow global warming.

The IPCC was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization in November, 1988 to coordinate the world's scientific and policy making communities for effective and realistic action on climate change.

### Britain and U.S. disagree

When the first report, on the science of global warming, was finally approved May 25th, British Prime Minister Margaret Thatcher broke with the Bush Administration's skeptical, more-research-and-see position and said that if other countries did their part, the UK would reduce projected carbon dioxide emissions by 30% over 15 years.

IPCC scientists welcomed Mrs. Thatcher's statement but said it did not go far enough. Dr. John Houghton, Britain's chief meteorologist and chair of the scientific working group, said that "to stop global warming, you have to cut by 60% immediately." He said that only a few of its 90 scientists from 39 countries disagreed with the findings.

If nothing is done, global mean temperatures could rise 5.4°F by the end of the next century, the IPCC report said, and oceans would expand, polar ice melt and sea levels rise more than two feet, enough to submerge the Maldive Islands and coastal plains and cities. Millions of people will be forced to migrate.

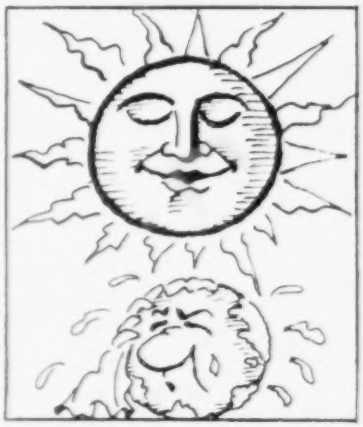
### U.S. influence in the world may diminish

Changes in rainfall patterns as a result of global warming may reduce grain production in the U.S. Warmer weather could benefit parts of Canada and the Soviet Union. This could have long term political consequences because U.S. influence is based, in part, on its grain surplus.

### Global warming's financial costs

IPCC's report gave examples of some economic projections of the costs of global warming. It pointed out that in some localities drinking water supplies will be disrupted. New York State can expect a 28 to 42% shortfall, which will cost $3 billion to rectify. The level of the Great Lakes may drop by as much as eight feet. Northern forests, unable to cope with rapid temperature change, will be damaged and perhaps die. Air pollution, especially in cities, is expected to get worse.

Some financial analysts estimate that slowing global warming could cost the U.S. $300 billion a year - the same amount as it now spends on its military. However, the Union of Concerned Scientists points out that "an energy efficiency program could cut carbon dioxide emissions 20% by the year 2000 and save $75 billion a year."



The UCS concludes that investing in renewable energy technologies during the 1990s could satisfy as much as half of America's energy needs within 30 years.

The IPCC reports go to the second World Climate Conference in Geneva this November and to the 45th General Assembly where they will be the foundation for intergovernmental treaty negotiations. The goal is to have a fully negotiated treaty ready for signing at the 1992 UN Conference on Environment and Development in Brazil.

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# UCSF Science Education Partnership Program
## produces a successful summer workshop

A few years ago scientist/faculty members at the University of California - San Francisco were upset at the quality of science education that their own children were receiving. They were also dismayed by the national reports on the condition of science teaching in the U.S. They decided that rather than wring their hands they would do something about it.

Their plan was to end the isolation between science professionals and pre-college science teachers. Now three years later the Science and Health Education Partnership at UCSF is dong just fine.

### Purpose of the Partnership

An agreement was reached between the Chancellor of the University and the Superintendent of the San Francisco School District.

The objectives of the program were:

1) to bring together individual teachers and research scientists
2) to provide surplus scientific equipment to teachers
3) to implement a city-wide competition in which student teams would construct and teach science lessons.

In the 1989-90 school year there were 116 student teams involved in the contest. Nine middle schools and ten high schools were represented.

### Some topics selected by the student teaching teams

Options for Contraception
Recycling
Hearing and Noise Pollution
Tropical Rain Forests
Effect of Oil Spills
Structure of DNA
Eating disorders
Separating Proteins by Size
Newton's Third Law
Chemistry of Drug Use and Addiction
Clouds
Sickle Cell Anemia
Evolution and Natural Selection
Things We Can Do to Save the Planet

Prizes of $1000 to $100 are awarded to finalists. Equally rewarding for the student teams is the good feeling they get from teaching the lesson to their peers in other classes or in other schools.

For more information about the program contact: Dr. Art Sussman SEP UCSF San Francisco, CA 94143- 0905

### Teachers and Scientists at SEP

Two thirds of the steering committee of the program are teachers so the thrust of the program is on helping teachers to teach science. During the regular school year the program brings scientists, science equipment and activities into the classrooms in the district.

This summer the committee added summer workshops to its activity list. The summer workshop participants received up-to-date information from practicing scientists and they used that information in the construction of activities for the classroom. The teacher/developers will test the activities in their classrooms this fall. After revision they will be distributed district wide. In some cases the teacher/developers will introduce them at workshops in their schools.

### The workshop results

One of the four workshops had as its theme- The Global Climate and the Greenhouse Effect.

The teaching materials developed will result in a three week unit on global climate change for San Francisco schools.

Since nobody wanted to "reinvent the wheel", the group incorporated some materials that had already been developed, including an adaptation of the measurement of carbon dioxide using bromthymol blue solution which appeared in the pages of this newsletter in March, 1988. (That activity is also described in The Science Teacher, "The Greenhouse Effect in a Vial", May, 1989)

The group also adapted an activity developed by teachers working at the Science Education Center at Lawrence Livermore National Laboratory.

### New activities and new lessons

An outline of the unit developed during the two week workshop and a description of the new activities for students in included in the pages that follow.

These activities have not yet been tested in the classroom. Your assistance is requested in improving them.

Please try these activities in your classroom and let us know the results.

### Your comments and suggestions are always welcome.

Send them to:
Climate Protection Institute
5833 Balmoral Drive
Oakland, CA 94619

## Outline for a unit on Global Climate Change developed at UCSF Science Ed. Partnership Workshop

**Day 1** The general subject is introduced by viewing "Hot Enough For You?" - a video in the Nova Series of television productions. A teacher advice sheet supplies background information, discussion questions and suggestions of places to fast forward the video to keep the lesson within the class period.

**Day 2 - 3** Laboratory activity on detecting carbon dioxide using bromthymol blue solution. (a modification of "The Greenhouse Effect in a Vial" The Science Teacher, May 1989.

**Day 4 - 5** Laboratory activity using the carbon dioxide and limewater reaction to (a) test for carbon dioxide in ambient air and to (b) model the production of calcium carbonate in the ocean. The follow-up includes discussion of the laboratory work and student conclusions.
(The activity is described on page 5 of this issue.)

**Day 6 - 7** Laboratory activity dealing with plants and carbon dioxide. Cuttings of elodea are placed in a slightly acidic bromthymol blue solution (olive green color) which contains some carbon dioxide. Some tubes are exposed to light, some kept in darkness and some are wrapped in transparent colored filters. The results are discussed and the ability of green plants to absorb carbon dioxide is connected to the global climate. (Developed at the Science Education Center, LLNL, Livermore CA. by teachers William Pence and Stephen Armstrong and is available free of charge. See note page 11)

**Day 8 - 10** Students construct and experiment with a device to demonstrate resonance. (An activity developed at the Exploratorium, San Francisco.) Physical models of molecules of carbon dioxide, methane and nitrogen are constructed. Experiment leads the students to conclude that objects absorb energy at frequencies that match their natural frequencies of vibration. The selective absorption of infrared radiation by greenhouse gases is discussed.
(These activities are described on pages 6 through 9 of this issue.)

**Day 11 - 12** Using charts and diagrams the teacher leads a discussion on the complete carbon cycle, both short term and long term, with emphasis on the connections to Earth systems and climate. The influence of climate on human activities and the possible consequences of global warming are discussed.

**Day 13** Classroom discussion develops examples of those human actions that produce increased emissions of greenhouse gases. A chart on "Actions that reduce the threat of global warming" is produced. The chart also develops the reasons why such actions would be beneficial in ways having nothing to do with global warming. (A sample of this chart is on page 10 this issue.)

**Day 14** As a review of the information, the class plays a version of the popular TV game show "Jeopardy" with categories and questions related to the topic of global warming. (Under development)

**Day 15** Evaluation of the students' understanding of the subject. Under development are questions that test for understanding of important concepts and the ability to think and communicate coherently about the problems and the possible actions that may be taken to ameliorate the situation.
(See page 11 of this issue)

The science educators responsible for the development of this unit are:
Kathy Soave, Washington High School, San Francisco
Emil Fogarino, Washington High School, " "
Lorraine Perry, Marina Middle School, " "
Erainya Neirro, Presidio Hill Middle School, " "
Art Sussman, Science and Health Education Partnership, UCSF
Richard Golden, Climate Protection Institute, Oakland

# Modeling a part of the long term carbon cycle

A Laboratory activity using the carbon dioxide and limewater reaction to:

a) test for carbon dioxide

b) model the production of calcium carbonate in the ocean.

**Background**

Students working with bromthymol blue solutions (BTB) fail to detect the presence of carbon dioxide in ambient air. One of the student conclusions from work with BTB is that the reaction is not sensitive enough to detect the low (approx. 0.03%) concentration of carbon dioxide in the atmosphere.

When carbon dioxide is bubbled through lime water a white precipitate of calcium carbonate forms. The degree of milkiness of the solution is an indication of the amount of carbon dioxide in the gas bubbled through. A precipitate will form when ambient air is passed through a lime water solution.

The long term carbon cycle removes carbon dioxide from the atmosphere and deposits it in the form of calcium carbonate on the ocean floor. The process begins when plants remove carbon dioxide from the atmosphere during photosynthesis. When the plant material decays in the soil, the carbon dioxide released dissolves in the groundwater forming carbonic acid. The carbonic acid acts on carbonate rocks and silicate minerals and yields dissolved calcium and bicarbonate ions. The ions are carried by groundwater to the ocean where plankton and corals incorporate them into shells and skeletons of calcium carbonate. The rain of dead organisms deposits the calcium carbonate on the ocean floor. As the buried material is moved deep underground the heat of the Earth produces new silicates and carbon dioxide. To complete the cycle, the carbon dioxide finds its way back into the atmosphere through volcanic eruptions and the bubbling of soda springs.

The reactions are as follows:

Carbonate rock weathering $CO_2 + H_2O + CaCo_3 \rightarrow Ca^{++} + 2HCO_3^-$

Silicate rock weathering $2CO_2 + H_2O + CaSiO_3 \rightarrow Ca^{++} + 2HCO_3^- + SiO_2$

Carbonates in the ocean $2HCO_3^- + Ca^{++} \rightarrow CaCO_3 + CO_2 + H_2O$

(Reference: "Modeling the Geochemical Carbon Cycle" Scientific American, Mar. 1989)

**Preparation**

Lime water is prepared by placing an excess of calcium hydroxide in distilled water. Stopper the container and shake well. Let the solution stand for 24 hours. Pour off the supernatant liquid and keep well sealed. If the solution is cloudy it may have to be filtered.

**Materials**

Lime water solution, aquarium air pump - (For each investigating team of 4 or 5 students) lime water, 5 test tubes, stub candle and match, beaker, glass plate, funnel with filter paper, graduated cylinder

**Team Activities**

A. Have the teams put 15 ml of lime water in their beakers. Cover with a glass plate and shake for 10 seconds. Pour the lime water in a test tube as a control. Place a candle in the beaker. Add the same amount of lime water. Light the candle and after it has burned for a minute, cover the beaker with a glass plate. When the candle has gone out shake the beaker just as before. Pour the lime water into a test tube and compare with the control. Ask the students to write down their conclusions.

B. In each of 5 test tubes put 15ml of lime water. One is set aside as a control. Have a student blow into the other four for periods of 10, 20, 30 and 40 seconds. Compare the results with the control.

C. By blowing for a long time get a small quantity of lime water as milky as possible. Filter the liquid and let the white substance dry overnight. Compare the powder obtained with chalk.

**Demonstration**

Using the aquarium air pump, bubble ambient air through a 15ml of lime water for various amounts of time. Compare the results with a control sample of lime water. Discuss the long term carbon cycle.

## Selective Vibrations
## Teacher Information

Activities that:

A. demonstrate the selective absorption of resonant frequencies (Good Vibrations)
B. model selective absorption of IR radiation by $CO_2$ and methane (Vibrating to a Special Beat)

**Background**

Every physical object that is free to vibrate has its own natural frequency, or frequencies, of vibration. If the frequency of vibration impinging on an object matches the natural frequency of the object, the energy of the vibration will be absorbed and the object will begin to vibrate at that resonant frequency. Common examples include; the rattling of objects when exposed to loud roars such as airplane engines, the "echo" effect of stringed musical instruments, the shattering of glass by a high pitched sound, and the tuning of a radio or TV receiver to a particular frequency.

The electron bonds that hold molecules together can vibrate like springs when they are energized by specific frequencies of vibration. The frequencies that will be absorbed depend on the physical construction of the molecules. Water vapor, carbon dioxide, methane, nitrous oxide, chloroflourocarbons (CFCs), and ozone are molecules whose natural frequencies of vibration match those in the infrared portion of the electromagnetic spectrum. The energy they absorb is re-radiated in all directions. That portion which is directed back to the surface becomes the heat of the greenhouse effect.

By means of a physical model the first of these activities will illustrate how the energy of varying frequencies of vibration are selectively absorbed. The students will construct and experiment with a model that demonstrates whether or not an object absorbs the energy of a specific frequency of vibration depends on its physical properties. In the concluding discussion it is important to point out to students that the electromagnetic spectrum is a range of varying frequencies of vibration. It may be beneficial to review the electromagnetic spectrum with emphasis on the differences among ultraviolet, visible light and infrared radiations.

**Suggestions for beginning the lesson:**

What is the greenhouse effect? (Retention by certain gases in the atmosphere of the infrared energy which is leaving the surface of the Earth.)

Why does our atmosphere "trap" infrared radiation? (Greenhouse gases have the property of selectively absorbing and re-radiating infrared radiation.)

What gases are responsible for this effect? (carbon dioxide, methane, nitrous oxide, CFCs, ozone)

Why these gases and not others? (Ask for student hypotheses. Make a list of them.)

Suggest to the students that in order to choose among conflicting hypotheses, when a direct experiment is too difficult or impossible, scientists sometimes may make use of other experiments in entirely different fields of study. General scientific principles which have been discovered elsewhere may be applied to make an immediate problem more easily solved. Sometimes models are made and experimented with to obtain information that can help make the real phenomena more understandable.

Both of these techniques will be used by the students in the two activities that follow. In (A) they will be asked to discover a general scientific principle from work with an apparatus which they will construct themselves. The application of that principle will help answer the question of why only certain gases have the greenhouse gas property.

When they do activity (B), the models they construct and experiment with will help them understand why the greenhouse gases intercept infrared radiation and do not obstruct visible light.

# Good Vibrations - Student Worksheet

(This activity is based on "Resonant Rings," from the Snackbook of the Exploratorium Teacher Institute, San Francisco, CA)

**Objective - Activity A:**

to construct and experiment with a device that demonstrates the principle of selective absorption of vibrations (resonance)

**Materials:** (for each investigating team of three or four students)

a manila folder or sheet of construction paper, masking tape or transparent tape, scissors, ruler, a mounting board of cardboard or corrugated board roughly 1 foot long and several inches wide

**Directions:**

Cut inch wide strips from the manila folder. Form and tape them into rings of different sizes. Start with a strip about 20 inches long and cut each succeeding strip about 3 inches shorter. The fold in the folder may interfere with your experiment so avoid it if you can. If necessary cut several straight strips. Overlap them about an inch and tape them to form strips that are long enough.

Tape the rings in size place so that they are parallel to the short end of the mounting board.

**Procedure:**

Take turns vibrating the mounting board from side to side. Try different frequencies of vibration. Can you make one of the rings vibrate very well while the others are almost motionless? Can you select which ring you want to vibrate while the others are still? What do you have to do to accomplish this?

**Conclusion:**

Have a team discussion of your results.

Agree on a statement which will describe what you have learned. Write your statement on a separate piece of paper and compare it with those of other teams that have completed their experimentation.

Have a class discussion to answer the question, "What general physical principle is involved in the activity you have just concluded?"

Perhaps it can help if you think of how a special thin walled wine glass can shatter when a certain high pitched sound is produced nearby. What energy is breaking the glass? Will it break all glasses? How is that like your paper rings experiment?

**Making connections:**

Our original question was, why do certain gases absorb infrared radiation and other gases do not? An additional question is, if they absorb infrared radiation why don't they also absorb regular light?

Make a sketch of the electromagnetic spectrum. Indicate the bands of frequencies for ultraviolet, visible light, and infrared radiation. Write down how they are the same and how they are different.

Are all gas molecules the same? How are they the same? How are they different? Write down your answers.

# Vibrating to a Special Beat
## Teacher Information - Activity B

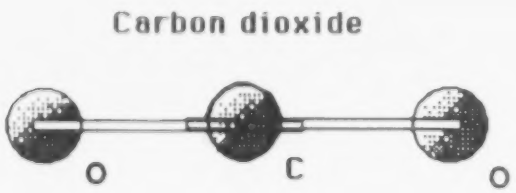
**Overview:**
By means of experimentation with student-made models of carbon dioxide, methane and nitrogen molecules it is discovered that only a relatively narrow range of frequencies of vibration are absorbed by the carbon dioxide and methane models and that the nitrogen model does not absorb these frequencies.

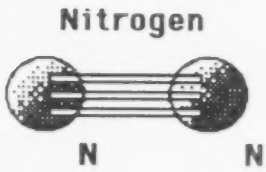
**Materials:** (per investigating team of 3 or 4 students)
10 old tennis balls, 7 -10" hacksaw blades (Standard alloy steel for fine cut works well. They are approx. $0.60 each and are cheaper than high strength steel blades. Used blades work equally as well.) masking tape, watch with second hand.

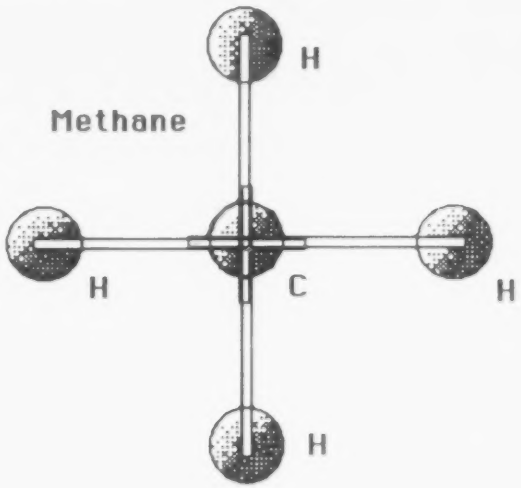
**Notes:**
1) Prepare tennis balls by cutting 3/4 inch slits for the insertion of hacksaw blades. (Exacto tool, wallboard knife, or small paring knife will do) Mark slits with a felt tip marker. See diagrams; 1 carbon "atom" must have 4 slits, the other carbon "atom" needs only two, 4 hydrogen "atoms" and 2 oxygen "atoms" need one slit each, 2 nitrogen "atoms" require 3 slits, one above the other.

2) If there is concern about safety due to the teeth on the blades, have the students cover the blade edge with masking tape before trying to insert them in the balls.

3) Break one hacksaw blade into 3 equal parts by clamping or holding it with a pair of pliers and bending the blade. These are for the nitrogen molecule which has a triple electronic bond.



# Vibrating to a Special Beat
## Student Worksheet - Activity B

**Directions: Model making**
Each team will build the following molecules. Be sure to label the appropriate balls; C, O, H, N
a) carbon dioxide model molecule - carbon (with 2 slits) gets 2 oxygens
b) methane model molecule - carbon (with 4 slits) gets 4 hydrogens
c) nitrogen model molecule - 3 slits between 2 nitrogen atoms

**A. Carbon dioxide model**
1) Insert one 10" hacksaw blade through a carbon atom. It should stick out about 1" on the other side.
2) Repeat the procedure with another hacksaw blade from the other side on top of the first blade.
3) Add an oxygen atom to each end so that the distance between each oxygen and the center carbon is 5"
4) Draw a line down the center of the blade to represent the double bond that holds atoms of carbon and oxygen together. (Note: Carbon atoms always have 4 chemical bonds.)

**B. Methane model**
1) Insert one 10" hacksaw blade through the carbon atom with 4 slits so that one end sticks out about 1" on the other side.
2) Repeat the procedure with another hacksaw blade from the other side, on top of the first blade.
3) Repeat steps 1 and 2 through the other pair of slits. You should now have a carbon atom with 4 "spokes." (What do they represent?)
4) Add one hydrogen atom to each of the ends so that the distance between each hydrogen and the central carbon is 5 inches.

**C. Nitrogen model**
1) Insert one short hacksaw blade into each of the 3 slits in one of the nitrogen atoms.
2) Add the remaining nitrogen atom by inserting the 3 blade ends into its slits.

**Experimentation:** When vibrating your model, keep the amplitude of vibration (the distance up and down) **less than 6 inches**. Be sure to try very slow frequencies (2 or 3 per sec.) as well as fast ones.

1) Hold your molecule by the central atom (with nitrogen use either end). Vibrate the model at different frequencies by shaking your hand. Look for differences in the movement of the hacksaw bonds?

2) Is there a frequency at which your model molecule absorbs the maximum of your energy output? (A frequency at which it is much easier to keep the model vibrating.)

3) If there is, determine this frequency, in vibrations per second, by counting the number of vibrations in a 5 second interval and dividing by 5. Do at least three trials and obtain the range of frequencies at which the maximum energy is absorbed.

4) Compare your results with the other investigating teams. Discuss the similarities and differences.

**Discussion:** Write out your team's response to the following:
1) Compare the resonant frequencies of the 3 model molecules.

2) What is the general physical principle which is involved in both this activity and the resonant rings? (What is it about an object that relates it to a particular frequency of vibration?)

3) From your observations of the resonant models, explain why some gases in the atmosphere selectively absorb infrared radiation and others do not.

4) How do you think an increase in greenhouse gases might affect the global climate?

**Conclusion:** Compile the responses of all the teams and discuss the results.

# ACTIONS THAT REDUCE THE THREAT OF GLOBAL CLIMATE CHANGE

| Greenhouse Gas | Actions that could be taken | Benefits to individuals, society, and the Earth, other than reducing the threat of climate change |
|---|---|---|
| | Reduce fossil fuel dependent transportation<br>Use mass transit  Avoid gas guzzlers<br>Use carpools  Use other fuels<br>Use bikes, walk more  solar, wind, biomass | Reduce land destruction due to strip mining, oil drilling and spills<br>Reduce the amount of forest destruction from acid rain<br>Improve the quality of the air, less air pollution<br>Improve the quality of life, less traffic, less stress<br>Saving gasoline saves money, and exercise is healthful<br>Protect the oceans, reduced oil drilling, less oil spills<br>Achieve energy independence, improved economics<br>Preserve fossil fuels for use by future generations |
| **Carbon dioxide**<br>Sources:<br>burning fossil fuels<br>deforestation<br><br>Contributes about 50% to global warming due to the increased greenhouse effect | Reduce fossil fuel use in the home and in industry<br>Improve insulation  Use energy efficient equipment<br>Practice energy conservation; reduce thermostat settings,  turn lights off<br>Develop cogeneration  Promote other energy sources | Preserve valuable raw materials<br>Save energy involved in transporting and processing of raw materials for manufacturing<br>Reduce waste and need for incineration or landfill space |
| | Recycle raw materials | |
| | Reduce deforestation; plant trees<br>Reduce use of paper and paper products | Save forests and preserve natural beauty<br>Preserve the habitats of wild animals and plants<br>Reduce soil erosion, prevent flooding |
| **Methane**<br>Sources:<br>cattle, fossil fuels, landfills, rice paddies, termites<br>Contributes about 16% to global warming | Eat less meat (lower on the food chain)<br>Reduce wastes and need for landfills by recycling<br>Reduce the deforestation that breeds termites<br>Prevent methane leakage from stoves and units that use natural gas | Healthier diet<br>Eating less meat provides more food for more people<br>Recycling preserves materials, forests, saves money and energy<br>Saves habitats for endangered species, preserves watersheds<br>Saves money |
| **Chlorofluorocarbons**<br>Sources: refrigerants, solvents, foamed plastics mfg.<br>Contributes about 20% | Develop and use environmentally save substitutes, Capture and recycle CFC's from old refrigerators and air conditioners, Support international protocols on limiting their use | Reduce the destruction of the ozone layer in the upper atmosphere |
| **Nitrous oxide** - About 6%<br>Sources: fertilizer use, burning of fossil fuels and biomass | Reduce use of fertilizer by using organic growing techniques, Act to reduce fossil fuel uses as listed above | Preserve soil for immediate and long-term use<br>Reduce runoff water pollution<br>Benefits of reducing fossil fuel use as listed above |
| **Ozone** (in the lower atmos.)<br>Sources: car exhaust, factory emissions  About 8% | Reduce car emissions by using cars less and by maintaining engines in good working order | Reduce respiratory deaths and distress of elderly in cities<br>Save money, Reduce air pollution and bad effects on plants<br>Numerous benefits of reducing gasoline consumption |

## Evaluating Student Knowledge the New Way

by
Dr. Art Sussman
Science and Health Education Partnership, UCSF

In the context of the existing crisis in science education, many of us are piloting materials that are more hands-on, thematic and concept oriented than standard lessons which emphasize vocabulary.

However, if we evaluate student knowledge in homework assignments and tests by asking for factual responses, the students will memorize facts rather than develop thinking skills and concept frameworks.

Therefore, it is important to develop evaluation questions which test for and reward problem solving skills and understanding of central concepts.

As we concluded our work on the unit on Global Climate Change we began to think about developing such questions. Here are some preliminary examples:

1. The star around which a distant planet revolves emits energy mostly in the blue region of the electromagnetic spectrum. Remote spacecraft bring back to Earth samples of the planet's plant life.
What do you think might be the color of the plants? Explain.

*(In order to maximize the absorption of energy (blue light), the plants would probably be yellow or red. Since a blue object does not absorb blue light, they would not be blue.)*

2. Gasoline ($C_8H_{18}$) reacts with oxygen to form carbon dioxide and water.
If one gallon of gasoline weighs 2,800 grams, how many grams of carbon dioxide are produced by burning a gallon of gasoline?

*(This is a good question for chemistry classes. By balancing the chemical equation students discover that 8 moles of carbon dioxide are formed for each mole of gasoline. Further calculations show that the 2,800 grams of gasoline produce 8,600 grams of carbon dioxide.)*

3. Scientists have just discovered a new compound. It has been named UGOT-2B-KIDIUM. This gas resonates at visible light frequencies but *not* at infrared frequencies.
What would be the effect on global climate if such a gas were released in vast quantities into the atmosphere? Explain.

*(The gas would be an anti-greenhouse gas. By absorbing incoming light and letting infrared radiation escape, it would act to shade the Earth. This hypothetical gas would have the effect of cooling the global climate.)*

As you work on the concepts of global climate change and develop problem-solving or concept-testing evaluation questions, please forward them to this newsletter so that they may be shared.

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"The longer the world waits to act, the greater will be the climate change that future generations will have to endure."

from "Global Warming Trends,"
Scientific American, August, 1990

## Freebies

### LLNL offers "Greenhouse Effect and Global Climate Change - 17 Day Unit"

The experiment mentioned on page 4 is part of a larger unit on global warming developed by teachers William Pence and Stephen Armstrong, working in collaboration with the Science Education Center of the Lawrence Livermore National Laboratory.

The materials are available free in draft form from:
Science Education Center
P.O. Box 808 L-793
Livermore, CA 94550
Contact person:
Christine Shannon

### Dept. of Energy Booklet

The Department of Energy has provided us with copies of its 36 page booklet, "Atmospheric Carbon Dioxide and The Greenhouse Effect." It is available to you for the asking and the postage.

The booklet includes discussion of:
How do scientists estimate future climate change?
How is increasing atmospheric carbon dioxide likely to affect plants -- and agriculture, forests, and water supplies?
Is sea level rising?
What can we do about the increase in atmospheric carbon dioxide and its effects?

To obtain a copy:
You must send a self addressed 9" x 12" envelope with $1.00 postage (3rd Class) or $1.25 (1st Class) ($1.40 in Canada) to:
Climate Protection Institute
5833 Balmoral Drive
Oakland. CA 94619

### *Teacher's Guide Just Published*

**"Global Warming and the Greenhouse Effect" from LHS**

Eight sessions of hands-on activities for grades 7-10 are now available from the Lawrence Hall of Science, U. of C.- Berkeley. This latest in the GEMS series of teacher guides enables students to build a "greenhouse model" of the atmosphere and compare amounts of carbon dioxide in car exhaust, human breath and in the air. Students also analyze articles written from various viewpoints, discuss the consequences of sea level rise, make an "effects wheel," and more.

To obtain a copy: Send for the entire GEMS series order form or Send $11.00 plus $1.50 for shipping to GEMS - Lawrence Hall of Science University of California, Berkeley, CA 94720

Please make checks payable to: Regents of the University of California
Purchase orders accepted ONLY for orders of $25 or more

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**COMPUTER PROGRAM ON GLOBAL CLIMATE CHANGE**

Below is the "table of contents" of our HyperCard program. It will operate on a Macintosh with 2 disk drives or a hard disk.

If you would like the three diskette set, send $15 to CPI.

**In this issue**


- A teenager speeds international agreement ..... Page 1
- UN scientists report on climate change ..... 2
- Successful UCSF summer workshop ..... 3
- Outline for a 15 day unit on climate change ..... 4
- Long term carbon cycle activity ..... 5
- Selective Vibrations activities (absorbing infrared) ..... 6 - 9
- Activity on reducing the global climate threat and doing other good things at the same time ..... 10
- Evaluating student knowledge the new way ..... 11
- Freebies from LLNL and DOE ..... 11



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*"The amount and rate of climate change depend on how people behave."*
Dr. Stephen Schneider


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